AUTO SERVICE and REPAIR

Stockel / Stockel

Sun INDUCTIVE TIMING LIGHT
Snap-on

Auto Service and Repair

Servicing, Locating Trouble, Repairing Modern Automobiles, Basic Know-How Applicable to All Makes and Models

by

MARTIN W. STOCKEL

and

MARTIN T. STOCKEL

South Holland, Illinois
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IMPORTANT SAFETY NOTICE

Proper service and repair is important to the safe, reliable operation of motor vehicles. Procedures recommended and described in this book are effective methods of performing service operations. Some require the use of tools specially designed for the purpose and should be used as recommended. Note that this book also contains various safety procedures and cautions which should be carefully followed to minimize the risk of personal injury or the possibility that improper service methods may damage the engine or render the vehicle unsafe. It is also important to understand that these notices and cautions are not exhaustive. Those performing a given service procedure or using a particular tool must first satisfy themselves that neither their safety nor engine or vehicle safety will be jeopardized by the service method selected.

This book contains the most complete and accurate information that could be obtained from various authoritative sources at the time of publication. Goodheart-Willcox cannot assume responsibility for any changes, errors, or omissions.

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INTRODUCTION

AUTO SERVICE AND REPAIR tells and shows how to service, troubleshoot, and repair modern automobiles. It contains information on the latest developments in the automotive field, including computer control, antilock brakes, and air bag systems. The material in this text is easy to understand and applicable to all automobiles.

The textbook teaches essential skills, encourages the development of good work habits, and emphasizes safety. It is comprehensive, detailed, and profusely illustrated. Many of the drawings were prepared especially for use in this text.

AUTO SERVICE AND REPAIR provides instruction as recommended by the Standards for Automotive Service Instruction in Schools. It is intended for beginners who need a sound, thorough foundation in fundamentals. It also helps those now engaged in automotive service and repair who want to increase their skills and earnings.

Each chapter begins with several objectives that tell you what will be learned. Technical terms are defined when first mentioned and a glossary is provided at the rear of the book.

WORKBOOK for AUTO SERVICE AND REPAIR is also available. It is a convenient study guide and shop activity guide directly related to this textbook.

MARTIN W. STOCKEL
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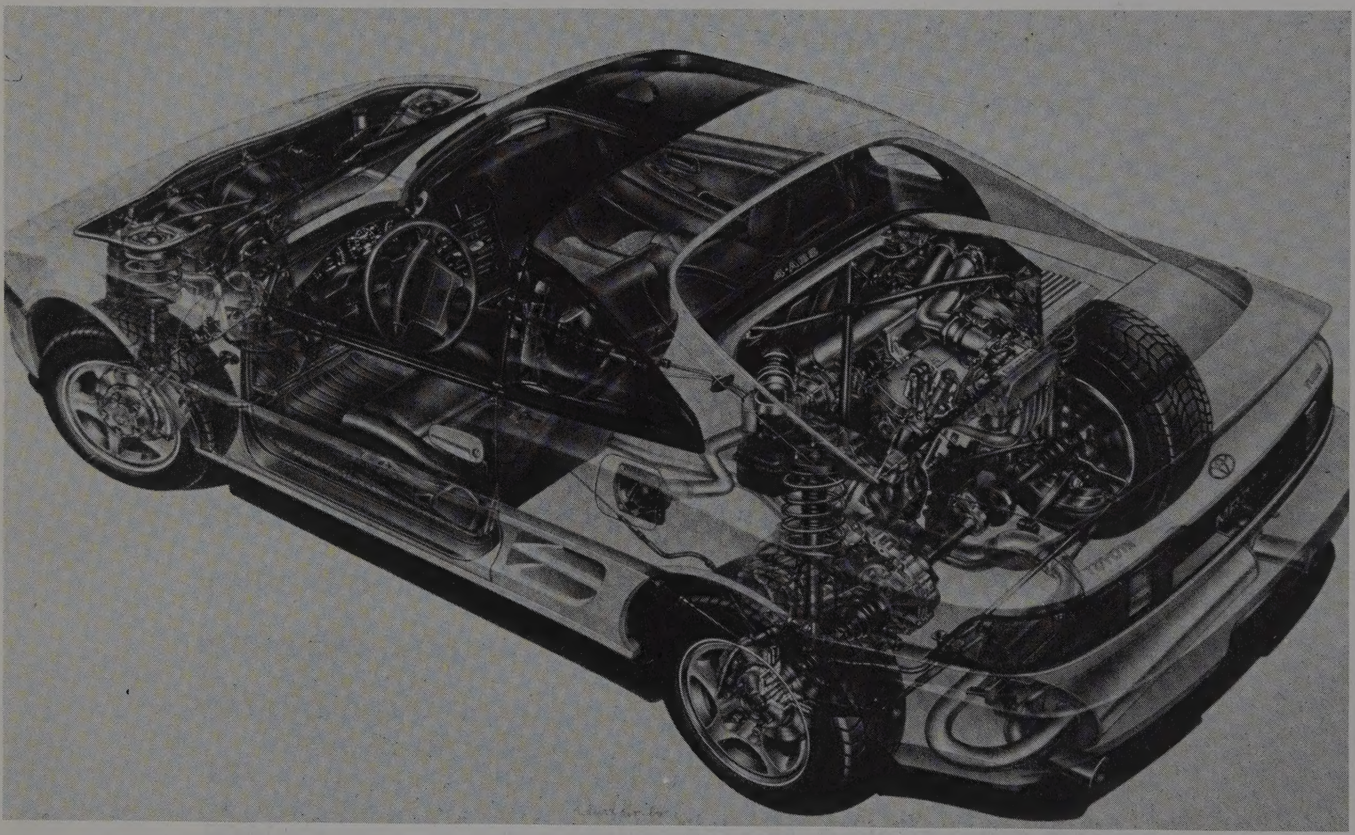
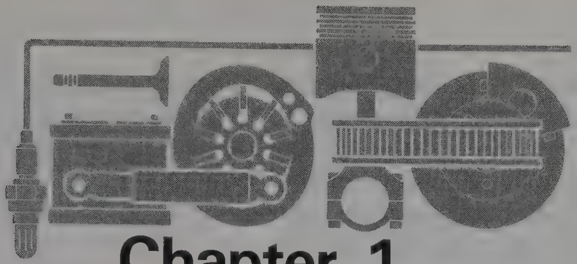


Cutaway view illustrating the various systems in a modern automobile. A top-quality, complete set of tools is necessary to effectively service today's complex vehicles. (Toyota)



Chapter 1

BASIC HAND TOOLS

After studying this chapter, you will be able to:
- ☐ Identify the most common automotive hand tools.
- ☐ Describe the proper use of auto hand tools.
- ☐ List the safety rules for hand tools.
- ☐ Select the correct tool for the job.

This chapter will cover the identification and use of basic hand tools. There are many other tools of a more specialized nature that are used by auto mechanics. THESE WILL BE ILLUSTRATED AND DISCUSSED IN THE CHAPTERS WHERE THEY APPLY.

TOOLS ARE IMPORTANT

Having a wide selection of quality tools available when needed will make your work more effective. Proper tools enable you to quickly perform the great number of jobs encountered by mechanics.

The cost of labor is high, and in fairness to both customer and garage, a mechanic cannot afford to waste time working with an inadequate selection of tools.

BUY TOP-QUALITY TOOLS

If you are, or plan to become, a professional mechanic, rule out inferior tools. The cheaper grades are usually made of poor material. They are thick and cumbersome to handle. They will fail sooner and slow down your work. Due to poor finishing, inferior tools will be harder to clean.

Top-quality tools are made of alloy steel and are carefully heat treated for great strength and long wear. They will be less bulky and will have a smooth finish. This makes them easy on the hands and quick to clean. The working surfaces are made to closer tolerances. Repair parts and facilities will be available. Quality tools may also be guaranteed.

There are a number of manufacturers that produce excellent tools. Selection of a specific brand must be left to the individual mechanic. REMEMBER: The initial cost of good tools may be high. However, considering pride of ownership, dependability, life span, ease of use and cleaning, they are, in the end, less expensive than tools of low quality.

PROPER CARE IS ESSENTIAL

Fast, efficient work and confusion cannot exist together. Keep your tools clean, orderly, and near at hand. A roll cabinet, in combination with a tool chest

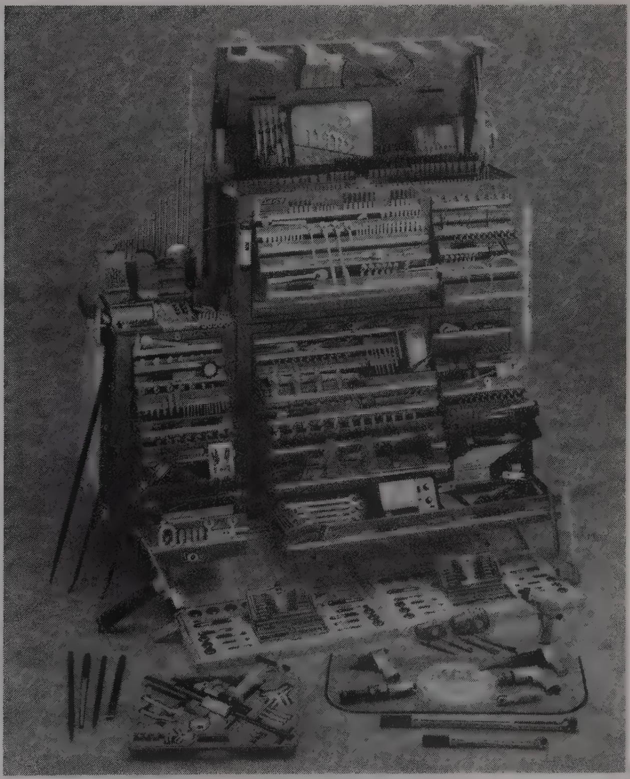


Fig. 1-1. A good way to store tools. Tools are shown arranged for display; normally they fit neatly into drawers. (MAC Tools)

and "tote" tray (small tray containing few selected tools) will provide proper storage and accessibility. Refer to Fig. 1-1.

Place delicate measuring tools in protective cases. Separate cutting tools (files, chisels, drills) to prevent damage to cutting edges. Tools that rust should be lightly oiled. Place heavy tools by themselves. In general, attempt to keep the most frequently used tools handy. Keep sockets, open end, and box end wrench sets together. REMEMBER: THE LITTLE TIME IT TAKES TO KEEP YOUR TOOLS CLEAN AND ORDERLY WILL BE GREATLY OFFSET BY THE TIME SAVED ON THE JOB!

HAMMERS

Ball peen, plastic tipped, brass, lead, rawhide, and rubber hammers should be included in every mechanic's selection. Various sizes of each are desirable.

The ball peen is used for general striking, riveting, and gasket cutting. The plastic, lead, and brass hammers are used to prevent marring of part surfaces. When using a hammer, grasp the handle firmly. Place your hand near the handle end. Strike so that the face of the hammer engages the work squarely, Fig. 1-2.

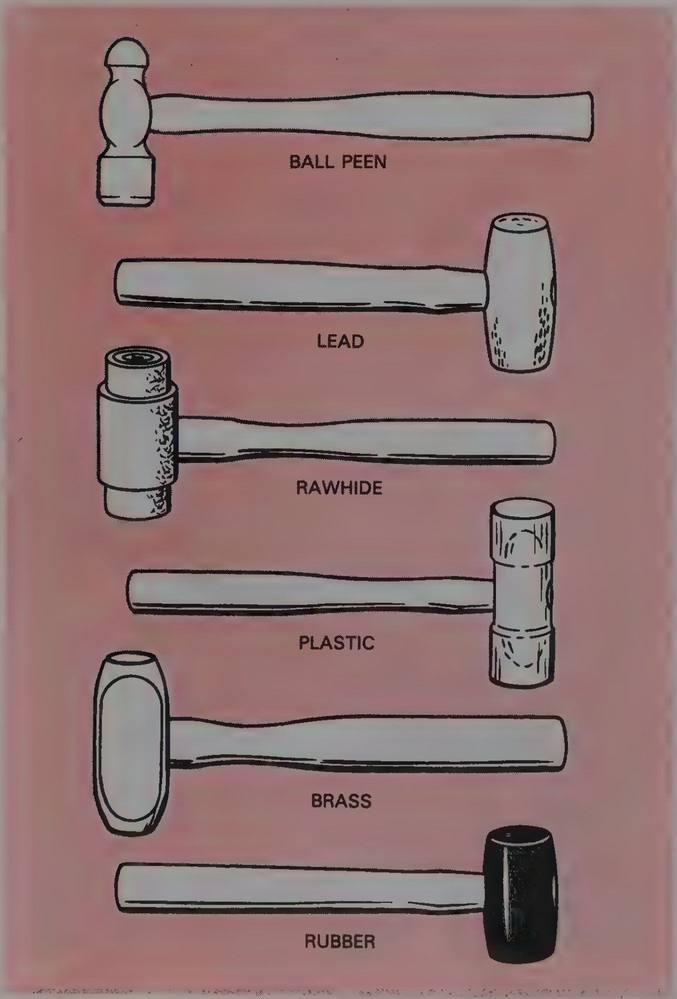


Fig. 1-2. Hammers. These basic types will cover all needs. (Deere & Co.)

DANGER! USE A HAMMER WITH CARE. DO NOT SWING IT IN A DIRECTION THAT WOULD ALLOW IT TO STRIKE SOMEONE IF IT SLIPPED FROM YOUR GRASP. MAKE CERTAIN THE HANDLE IS TIGHT IN THE HEAD AND THAT THE HANDLE IS CLEAN AND DRY.

CHISELS

Chisels are used for jobs such as cutting off rivet heads, bolts, and rusted nuts. Flat, cape, diamond, half-round, and "rivet buster" chisels should be available, Fig. 1-3.

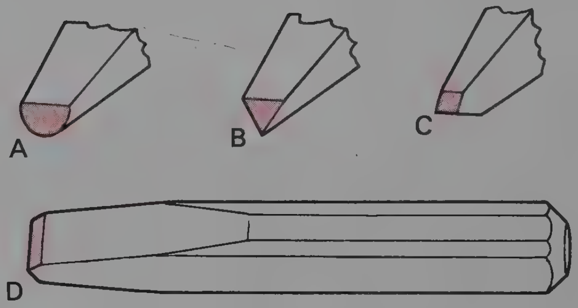


Fig. 1-3. Chisels. A—Half-round. B—Diamond. C—Cape. D—Flat.

Hold a chisel securely yet not tightly. Grasp it as far from the top as practical. This will protect your fingers somewhat if the hammer slips from the chisel head. For heavy hammering, a chisel holder should be used, Fig. 1-4.

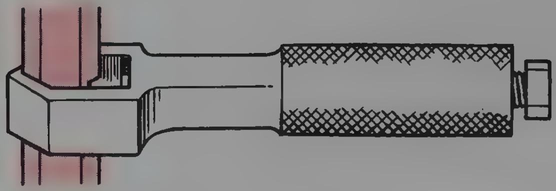


Fig. 1-4. Chisel holder. In use, the handle should be kept tight.

Keep the cutting edge sharp and the top chamfered (edges tapered). This reduces the possibility of small chisel segments breaking off and flying outward. WEAR GOGGLES WHEN USING A CHISEL. Refer to Fig. 1-5.

PUNCHES

Starting, drift, and pin punches are essential. A few sections of round brass stock in varying diameters are useful in driving parts that may be damaged with steel punches.

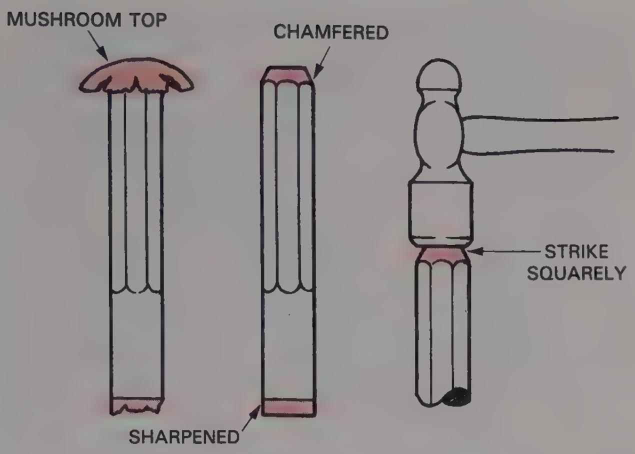


Fig. 1-5. Chisel at left is dangerous to use. Same chisel, after chamfering and sharpening, is shown at right.

A starting punch is used to start driving rivets, bolts, and pins from a hole. Due to its taper, it may fill the hole before the part is out. If it does, the job is completed with a drift punch. A pin punch is similar to a drift punch but has a smaller diameter driving shank. Pin punches are useful in removing small pins, bolts, etc., Fig. 1-6.

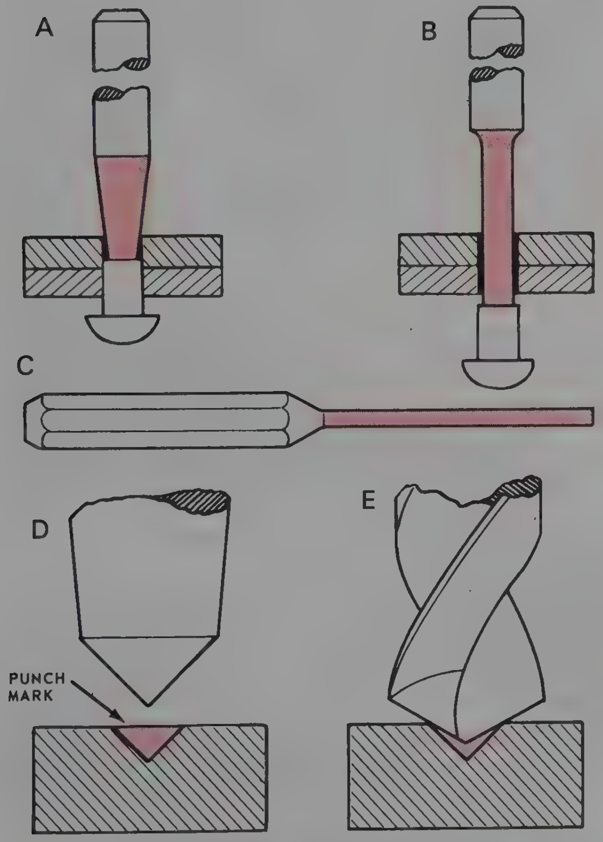


Fig. 1-6. Punches. A—Starting punch. B—Drift punch. C—Pin punch. D—Center punch marking work for drilling. E—Drill ready to make hole.

A center punch is needed to mark work before drilling. The small V-shaped hole will align the drill bit. The center punch is also useful for marking parts so they will be assembled in their original position, Fig. 1-6.

The aligning punch is very helpful in shifting parts so that the holes line up, Fig. 1-7.

Use care when sharpening chisels and punches. Grind slowly, keeping correct angles, and quench (dip in cold water) to prevent drawing the temper (overheating, turning the metal blue and rendering it soft). WEAR GOGGLES WHEN GRINDING!

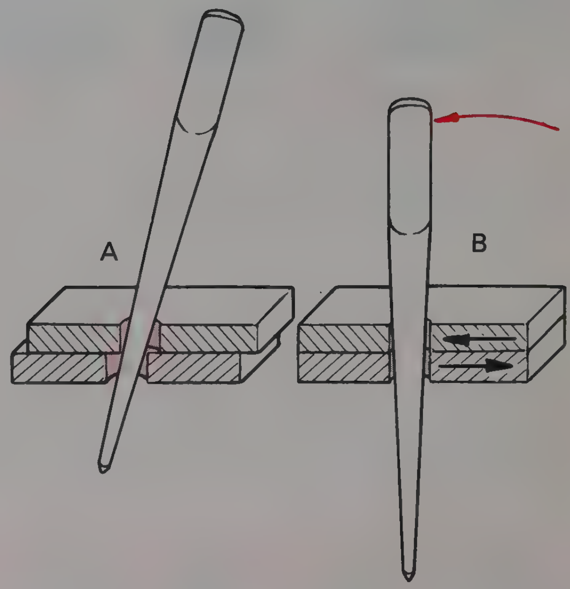


Fig. 1-7. Aligning punch. A—Run punch through holes as far as possible. B—Pull punch upright and force into holes. This will cause parts to shift into alignment.

FILES

The most frequently used files are the flat mill, round, square, triangular, and "point" files. Many other special shapes are also made, Fig. 1-8.

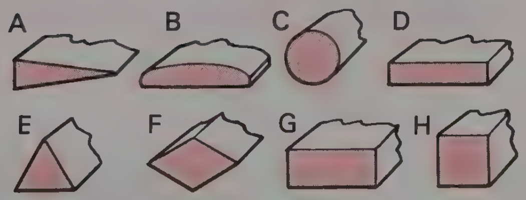


Fig. 1-8. File shapes. A—Knife. B—Half-round. C—Round. D—Flat. E—Triangle. F—Slitting. G—Pillar. H—Square.

The file's relative size and number of cutting edges per inch is one determination of file cut. In general, the softer the metal the coarser the cut needed. Three

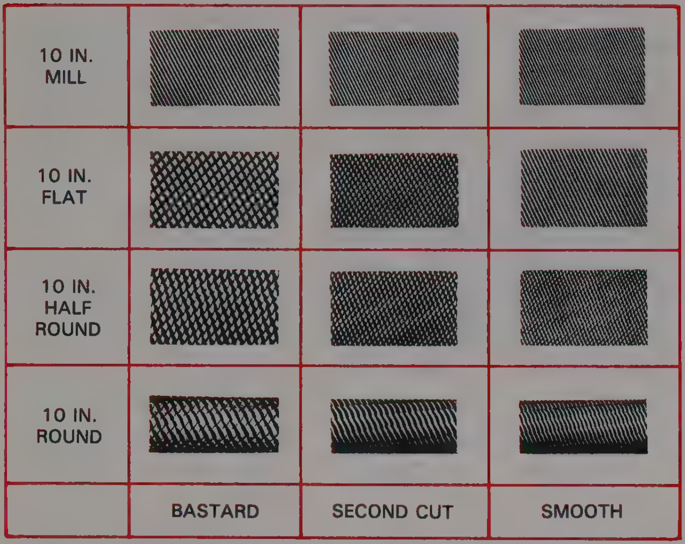


Fig. 1-9. Three different file cuts: bastard, second cut, and smooth. (Simonds File Co.)

popular cuts (bastard, second cut, and smooth) are shown in Fig. 1-9.

A file may be either single cut (single row of diagonal cutting edges at same angle), or double cut (two rows of diagonal cutting edges that cross each other at angle). Files may also be rasp and curve cut, Fig. 1-10.

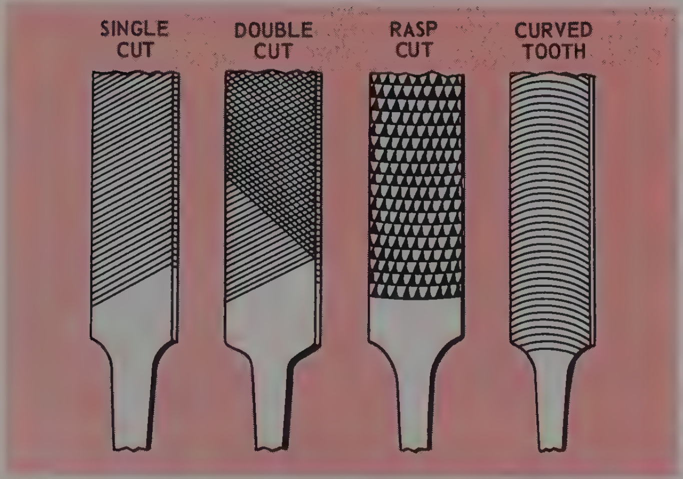


Fig. 1-10. File cuts. Each type works best for certain jobs. (Deere & Co.)

A typical single cut mill file is pictured in Fig. 1-11. Note the handle! BE SURE THE FILE HANDLE IS FIRMLY AFFIXED TO THE TANG BEFORE USING IT. This will provide a firm grip and will eliminate the danger of the tang piercing the hand, Fig. 1-11.

USING THE FILE

Grasp the file handle with the right hand (for right-handed persons) and hold the tip with the fingers of the left hand. On the forward stroke, bear down with enough pressure to produce good cutting. On the return stroke, raise the file to avoid damaging the cutting edges.

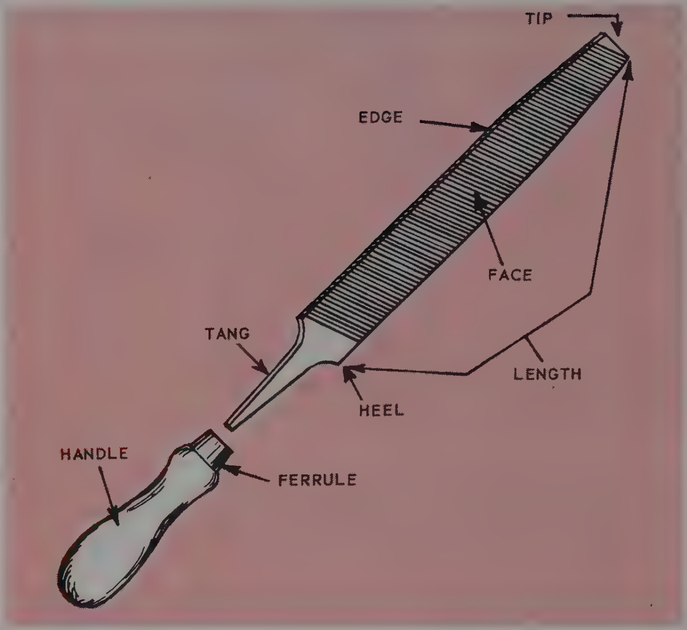


Fig. 1-11. Typical single cut mill file.

Control the file to prevent rocking (unless filing round stock). It takes a great deal of practice to become expert at filing. A file, in the hands of a professional, can do amazingly accurate work.

Keep the file clean and free of oil. Use a file card (special wire brush) to clean the teeth. Regular blackboard chalk may be rubbed into the file to help prevent clogging.

Use a cut suitable for the work. Coarse cuts are best for soft metals (aluminum, brass, lead). Finer cuts work well on steel. Your choice will also depend upon the finish desired.

ROTARY FILES

The rotary file is chucked in an air drill or an electric drill. It is very handy for blind holes or recesses where a regular file will not work. Several useful shapes are shown in Fig. 1-12.

GRINDERS

The auto mechanic will often use a grinder to sharpen tools, and rework parts. Grinding, like all shop operations, requires skill and careful handling.

Several types of grinders are found in most garages. You should be familiar with all of them.

BENCH OR PEDESTAL GRINDER

This grinder is commonly used to sharpen tools and remove stock from various parts. It is often fitted with

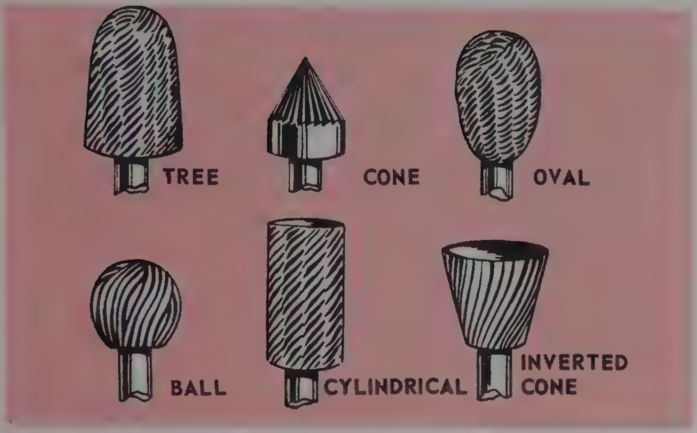


Fig. 1-12. Rotary files.

a grinding wheel on one side and a wire wheel for cleaning on the other. If mounted on a bench, it is referred to as a bench grinder, Fig. 1-13, A. If mounted on a stand, it is called a pedestal grinder.

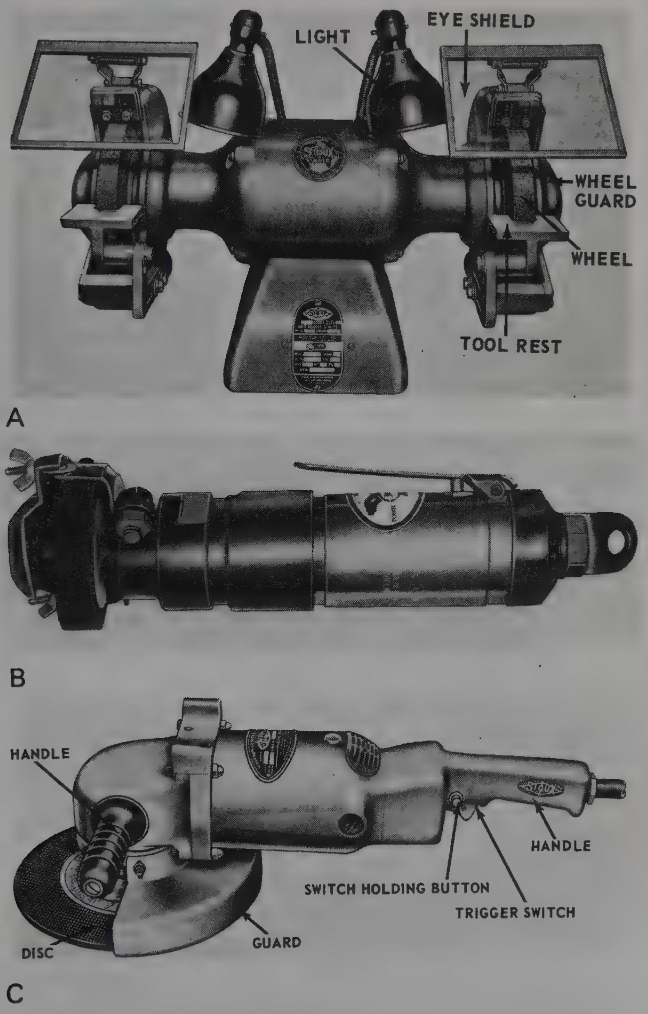


Fig. 1-13. A—Bench grinder. B—Hand-held wheel grinder. C—Disc grinder or sander.

HAND-HELD GRINDER AND SANDER

These tools include grindstones, wire wheels, and abrasive discs. They are used in body and fender work, carbon and rust removal, smoothing and cleaning welds, porting, and relieving. B and C in Fig. 1-13 show two of these power tools.

OTHER GRINDERS

Other types of specialized grinders (brake grinders, valve grinders, crank grinders) are also found in auto shops. The use of these tools will be discussed in the chapters relating to the work they are designed to perform.

SAFETY RULES FOR GRINDERS, SANDERS, AND WIRE WHEELS

Grinders, improperly used, are dangerous! They are responsible for many serious and lasting injuries to the eyes, hands, and face. Realizing this, the competent mechanic must ALWAYS observe the following safety rules:

1. ALWAYS WEAR GOGGLES.
2. KEEP ABRASIVE STONES TIGHT, CLEAN, AND TRUE.
3. ALLOW THE GRINDER TO REACH FULL RPM BEFORE USING, STAND TO ONE SIDE UNTIL FULL WHEEL SPEED IS REACHED.
4. KEEP THE TOOL REST, WHERE USED, AS CLOSE TO THE WHEEL AS POSSIBLE.
5. STAND TO ONE SIDE OF THE STONE AS MUCH AS FEASIBLE.
6. KEEP PERSONS WITHOUT GOGGLES AWAY FROM THE TOOL YOU ARE USING.
7. HOLD SMALL OBJECTS WITH VISE-GRIP PLIERS RATHER THAN BY HAND. THIS WILL HELP AVOID GRINDING YOUR FINGERS OR HAVING THE OBJECT SEIZED BY THE WHEEL AND THROWN VIOLENTLY.
8. FOR HEAVY GRINDING, WEAR LEATHER GLOVES.
9. BE CAREFUL NEVER TO STRIKE A GRINDING WHEEL WHILE REVOLVING. IT MAY SHATTER AND LITERALLY EXPLODE.
10. PROTECT YOUR EYES BY WEARING AN APPROVED FACE SHIELD OR GOGGLES.
11. AVOID GRINDING IN THE PRESENCE OF EXPLOSIVE VAPORS (GASOLINE, PAINT THINNER, BATTERIES).
12. WHEN INSTALLING A NEW STONE MAKE CERTAIN IT IS DESIGNED FOR THE RPM OF THE GRINDER.
13. WHENEVER POSSIBLE, HAVE THE GRINDING WHEEL GUARD IN PLACE TO MINIMIZE THE DANGER OF FLYING PARTS.

14. REMEMBER, GRINDERS AND WIRE WHEELS CAN BE DANGEROUS TOOLS–ALWAYS USE THEM WITH CARE!

DRILLS

The mechanic has many uses for twist drills. The better quality drills, made of high-speed steel, will do a good job of drilling on most parts of the car. They can be readily ground without drawing their temper. Carbon steel twist drills are cheaper. They require frequent sharpening and lose their temper if slightly overheated.

A set of fractional size drills from 1/16 to 1/2 in. (29 drills to set) plus 9/16, 5/8, and 3/4 in., a set of number drills from 1 to 60, and a set of metric drills (1 mm to 13 mm) will handle most requirements. A typical twist drill is illustrated in Fig. 1-14.

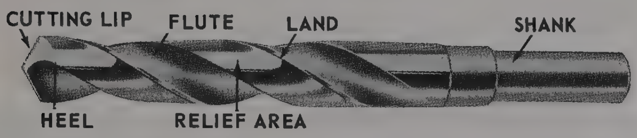


Fig. 1-14. Typical twist drill.

SHARPENING DRILLS

Select a new 1/2 in. drill. Without starting the grinder, place the cutting edge of the lip either on the side or on the face of the wheel. Keep the shank lower than the tip. With a slight rocking, pivoting motion, cause the drill lip surface to slide across the wheel. Always start at the cutting edge and end at the heel. Keep trying this until you can go through the sharpening motion. Keep the lip in proper contact at all times.

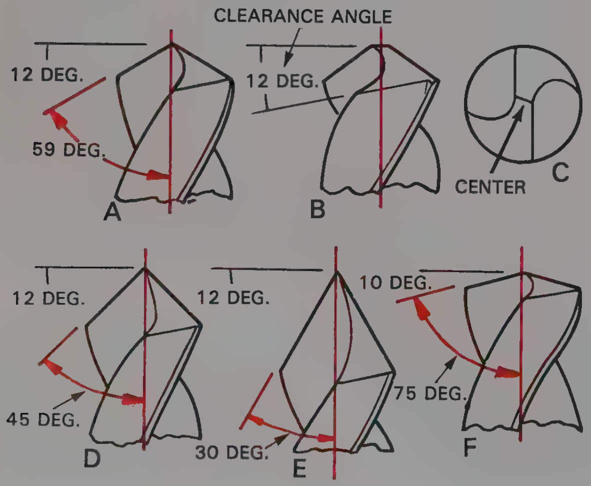


Fig. 1-15. Drill lip angles. A, B, and C—General purpose point. Angle shown in B is for clearance. D—For cast iron and aluminum. E—Rubber, wood. F—Hard, tough steel. Note that "back rake" or clearance angles are the same in all except F. Clearance angles are shown in black; lip angles in color.

Now select an old drill, 3/8 in. or larger. Start the grinder (goggles on, safety shield in place) and try sharpening the drill. Remember to start at the cutting edge and finish at the heel. Both cutting lips should be the same length and angle. The 12 deg. angle, formed between the cutting lip and heel, is very important. The heel must be lower in order for the drill to cut, Fig. 1-15.

Although drill lip angles are varied for work in different metals, the angles shown in Fig. 1-15 will produce good all-around cutting.

Grind slowly and quench frequently by dipping the drill into cold water. Avoid overheating, especially with carbon steel drills. Use a simple drill gauge to help you get the proper angles, Fig. 1-16.

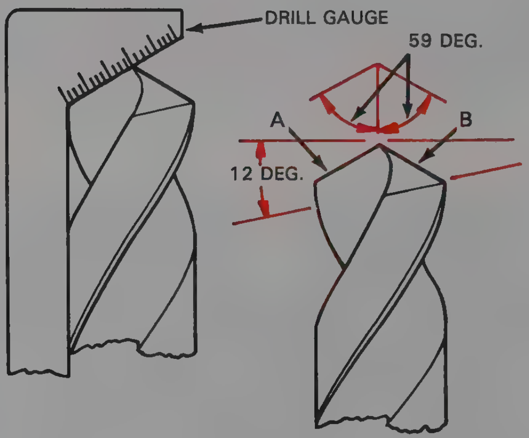


Fig. 1-16. Using a drill gauge. This simple gauge will check lip angles and length. Lip lengths A and B must be the same.

If you have sharpened the drill correctly, it will cut quickly and smoothly. Both lips will be cutting. An equal amount of chip or curl will be evident, Fig. 1-17.

USING DRILLS

Center punch the spot to be drilled. Check the drill tightly. When drilling cast iron, pot metal, aluminum,

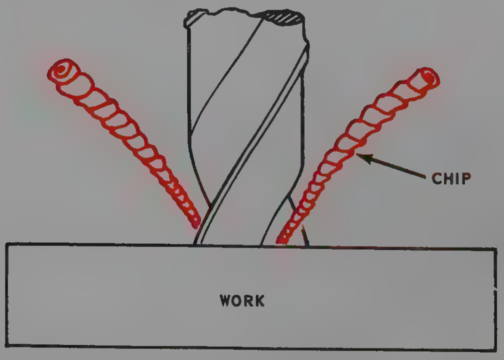


Fig. 1-17. Drill cutting properly. If the drill is sharpened correctly, each lip will produce a similarly sized chip.

and thin body metal, cutting oil is not necessary. When drilling steel, a small quantity of cutting oil will be helpful.

Keep the drill at the proper angle and apply enough pressure to produce good cutting. Just before the drill breaks through, ease up on the pressure to prevent grabbing.

Securely fasten the piece to be drilled. On thin stock, be careful to hold it down as it has a tendency to climb up the flutes. Fig. 1-18 pictures a 1/4 in., air-powered hand drill. The 3/8 in. hand drill is handy with medium size drills. A 1/2 in. size will handle heavy drilling, turning cylinder hones, etc.

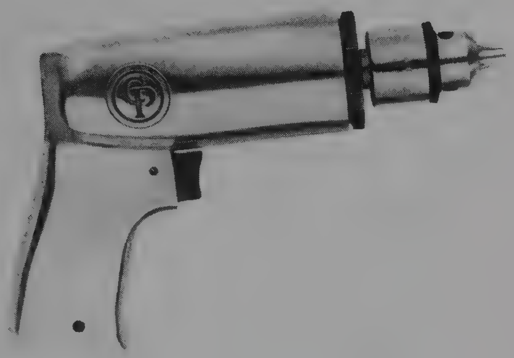


Fig. 1-18. Air-powered hand drill. (Chicago Pneumatics)

SAFETY RULES FOR THE USE OF DRILLS

1. UNPLUG THE CORD BEFORE INSERTING OR REMOVING A DRILL FROM THE CHUCK. (If the drill starts while you are holding the chuck wrench in the chuck, it might rip your hand badly.)
2. KEEP LOOSE CLOTHING, SLEEVES, TIES, PANT LEGS, AND HAIR AWAY FROM THE DRILL.
3. MAKE CERTAIN THE DRILL IS PROPERLY GROUNDED. . . .ALL ELECTRIC DRILLS PRESENT DANGER OF SHOCK.
4. NEVER USE POWER TOOLS OF ANY KIND WHILE STANDING IN WATER OR ON WET GROUND.
5. SECURE THE WORK TO BE DRILLED. (If the drill grabs and the work is loose, it can begin to spin with a vicious cutting force.)
6. WEAR GOGGLES WHEN GRINDING DRILLS.
7. DO NOT USE ANY POWER TOOL IN THE PRESENCE OF EXPLOSIVE VAPORS.

REAMERS

Reamers are used to enlarge, shape or smooth holes. They produce a finish that is much smoother and more accurate than that produced by drilling. Some reamers may be adjusted and others are of a fixed size. Both straight and tapered reamers are needed. They may use either straight or spiral flutes, Fig. 1-19.

Use cutting oil when reaming. Turn the reamers in a CLOCKWISE direction only - both on entering and leaving the hole. Take small cuts around .001-.002 in. (0.025-0.050 mm). Reamers are very hard and the cutting edges chip readily. Wipe down with oil and keep them in a protective container.

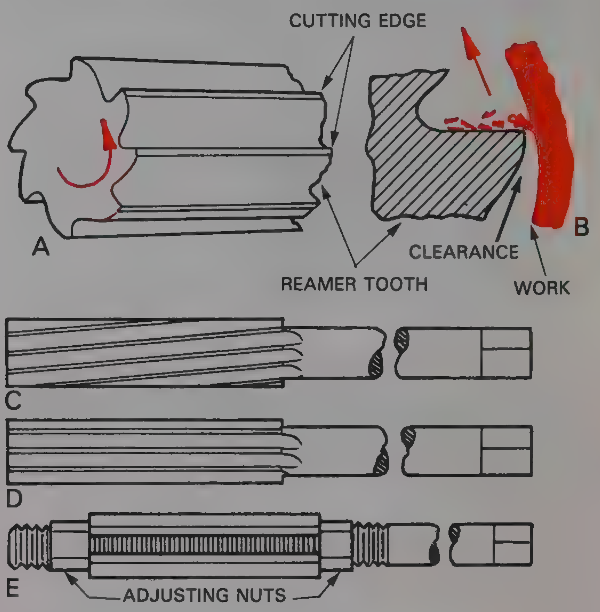


Fig. 1-19. Reamers. A—Enlarged section showing reamer tooth construction. B—Reamer tooth removing stock. C—Nonadjustable, spiral flute reamer. D—Nonadjustable, straight flute reamer. E—Adjustable straight reamer. It is opened and closed by removing adjusting nuts.

TAPS AND DIES

Taps are used for cutting internal threads. Dies are used to cut external threads on bolts, screws, and pipe. The mechanic should have a set of taps and dies covering the Unified National Fine and the Unified National Coarse threads (these are fully covered in the chapter on fasteners). This set would have machine screw sizes 1 through 12, plus the 1/4 through 5/8 by sixteenths, plus a 3/4, 7/8, and 1 in. size. A set of metric size taps and dies is also needed.

There are many kinds of taps but for general garage use, the taper, plug, bottoming, and pipe taps will do nicely. The taper tap has a long chamfer (about 10 threads) that allows it to start easily. It cannot, however, be used in blind holes where the thread must run almost to the bottom. The plug tap has a shorter chamfer (about 5 threads). With care, it can be started successfully. It is useful for open holes and for blind holes. The bottoming tap has a short chamfer (about 1 thread) and is used in blind holes to finish the thread to the bottom of the hole. The plug tap should be used first. When it strikes bottom, the bottoming tap should be used.

The pipe tap is tapered over the full length (about 3/4 in. per ft.). It is used to tap holes for pipe fittings.

Taper, plug, bottoming, and machine screw taps are illustrated in Fig. 1-20.

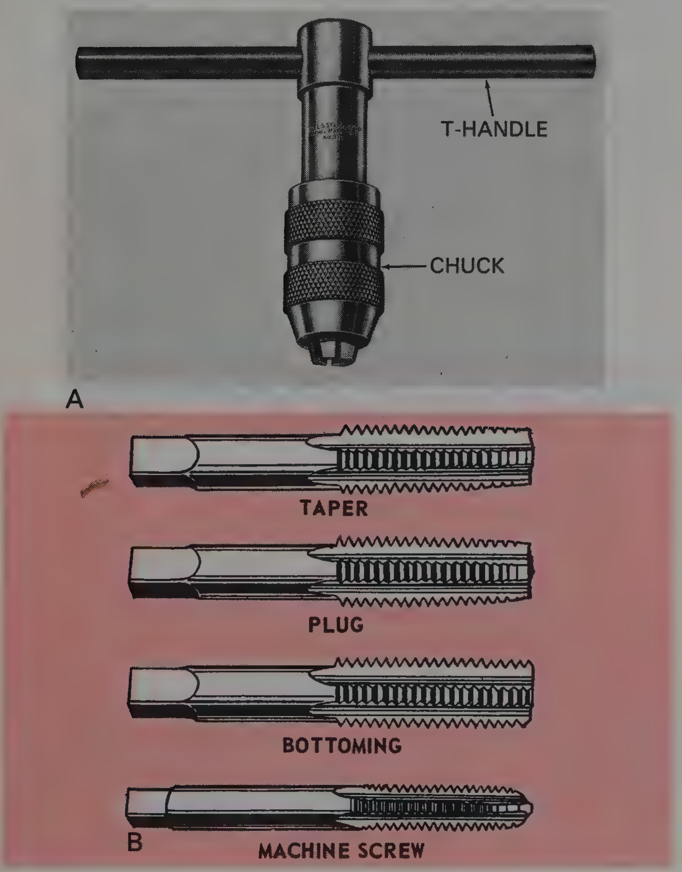


Fig. 1-20. A—Typical taps. Amount of chamfer varies with each type. B—One form of tap wrench, chuck holds tap. T-handle permits turning. (Starret Co.)

TAPPING

First, determine exactly the number of threads per inch and the diameter of the screw that will enter the hole. Referring to a tap drill size chart, Fig. 1-21, select the proper tap size drill.

For example, say that you desire a threaded hole for a 7/16 in. screw with 20 threads per inch. Looking at the chart, you will find that a 7/16 in., 20 threads per inch, is a Unified National Fine size. Going directly across from the 7/16 in. UNF, notice a column marked "Tap Drill Size." In this case, the tap drill size for a 7/16 in. x 20 is a 25/64 in. drill.

What would be the correct tap size drill to use for a screw 3/8 in. in diameter with 16 threads per inch? Check the chart, you will find it to be 5/16 in.

TAP DRILL SIZES
Recommended for
AMERICAN NATIONAL SCREW THREAD PITCHES

COARSE STANDARD THREAD (N. C.)
Formerly U. S. Standard Thread

Sizes	Threads Per Inch	Outside Diameter at Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	64	.073	53	0.0595
2	56	.086	50	0.0700
3	48	.099	47	0.0785
4	40	.112	43	0.0890
5	40	.125	38	0.1015
6	32	.138	36	0.1065
8	32	.164	29	0.1360
10	24	.190	25	0.1495
12	24	.216	16	0.1770
1/4	20	.250	7	0.2010
5/16	18	.3125	F	0.2570
3/8	16	.375	5/16	0.3125
7/16	14	.4375	U	0.3680
1/2	13	.500	27/64	0.4219
9/16	12	.5625	31/64	0.4843
5/8	11	.625	17/32	0.5312
3/4	10	.750	21/32	0.6562
7/8	9	.875	49/64	0.7656
1	8	1.000	7/8	0.875
1 1/8	7	1.125	63/64	0.9843
1 1/4	7	1.250	1 7/64	1.1093

FINE STANDARD THREAD (N. F.)
Formerly S.A.E. Thread

Sizes	Threads Per Inch	Outside Diameter at Screw	Tap Drill Sizes	Decimal Equivalent of Drill
0	80	.060	3/64	0.0469
1	72	.073	53	0.0595
2	64	.086	50	0.0700
3	56	.099	45	0.0820
4	48	.112	42	0.0935
5	44	.125	37	0.1040
6	40	.138	33	0.1130
8	36	.164	29	0.1360
10	32	.190	21	0.1590
12	28	.216	14	0.1820
1/4	28	.250	3	0.2130
5/16	24	.3125	I	0.2720
3/8	24	.375	Q	0.3320
7/16	20	.4375	25/64	0.3906
1/2	20	.500	29/64	0.4531
9/16	18	.5625	0.5062	0.5062
5/8	18	.625	0.5687	0.5687
3/4	16	.750	11/16	0.6875
7/8	14	.875	0.8020	0.8020
1	14	1.000	0.9274	0.9274
1 1/8	12	1.125	1 3/64	1.0468
1 1/4	12	1.250	1 11/64	1.1718

SPECIAL THREAD (N. S.)

Sizes	Threads Per Inch	Outside Diameter at Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	56	.0730	54	0.0550
4	32	.1120	45	0.0820
4	36	.1120	44	0.0860
6	36	.1380	34	0.1110
8	40	.1640	28	0.1405
10	30	.1900	22	0.1570
12	32	.2160	13	0.1850
14	20	.2420	10	0.1935
14	24	.2420	7	0.2010
1/16	64	.0625	3/64	0.0469
3/32	48	.0938	49	0.0730
1/8	40	.1250	38	0.1015
5/32	32	.1563	1/8	0.1250
5/32	36	.1563	30	0.1285
3/16	24	.1875	26	0.1470
3/16	32	.1875	22	0.1570
7/32	24	.2188	16	0.1770
7/32	32	.2188	12	0.1890
1/4	24	.250	4	0.2090
1/4	27	.250	3	0.2130
1/4	32	.250	7/32	0.2187
5/16	20	.3125	17/64	0.2656
5/16	27	.3125	J	0.2770
5/16	32	.3125	9/32	0.2812
3/8	20	.375	21/64	0.3281
3/8	27	.375	R	0.3390
7/16	24	.4375	X	0.3970
7/16	27	.4375	Y	0.4040
1/2	12	.500	27/64	0.4219
1/2	24	.500	29/64	0.4531
1/2	27	.500	15/32	0.4687
9/16	27	.5625	17/32	0.5312
5/8	12	.625	35/64	0.5469
5/8	27	.625	19/32	0.5937
11/16	11	.6875	19/32	0.5937
11/16	16	.6875	5/8	0.6250
3/4	12	.750	43/64	0.6719
3/4	27	.750	23/32	0.7187
7/8	12	.875	51/64	0.7969
7/8	18	.875	53/64	0.8281
7/8	27	.875	27/32	0.8437
1	12	1.000	59/64	0.9219
1	27	1.000	31/32	0.9687

TAP DRILL SIZES (METRIC)

Bolt Diameter (in mm)	Distance Between Threads (in mm)	Diameter of Drill (in mm)	Bolt Diameter (in mm)	Distance Between Threads (in mm)	Diameter of Drill (in mm)
M 2	0.4	1.6	M 22	2.5	19.5
M 2.2	0.45	1.75	M 24	3	21
M 2.5	0.45	2.05	M 27	3	24
			M 30	3.5	26.5
M 3	0.5	2.5			
M 3.5	0.6	2.9	M 33	3.5	29.5
M 4	0.7	3.3	M 36	4	32
M 4.5	0.75	3.7	M 39	4	35
			M 42	4.5	37.5
M 5	0.8	4.2			
M 6	1	5	M 45	4.5	40.5
M 8	1.25	6.8	M 48	5	43
M 10	1.5	8.5	M 52	5	47
M 12	1.75	10.2	M 56	5.5	50.5
M 14	2	12	M 60	5.5	55
M 16	2	14	M 64	6	58
M 18	2.5	15.5	M 68	6	62
M 20	2.5	17.5			

Fig. 1-21. Tap drill size chart. (Deere & Co.)

Drill the hole with a tap size drill. Holes over 1/4 in. should be drilled in at least two operations. Start with a small pilot drill about an 1/8 in. in diameter. Work up to the tap drill.

Using a suitable tap wrench, carefully start the tap. Cutting oil will help when tapping steel. After running the tap in one or two turns, back the tap up about one-half turn to break the chip. Repeat this process until fully tapped. Remember that taps are very brittle. Do

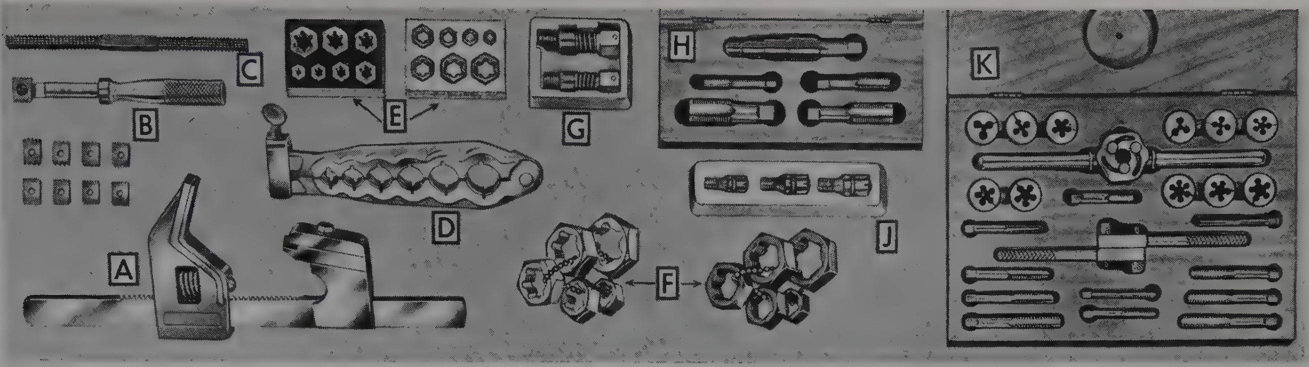


Fig. 1-22. Assorted taps and dies. (Snap-On Tools)

not strain them and be sure to keep the hole from clogging with chips. See Fig. 1-20.

The die is used much like the tap. After selecting a die of the correct size, place it in a die stock (handle). Apply cutting oil to the bolt and start the die. Use the same turn and back method used for tapping.

Dies are often adjustable so the thread fit can be changed. Adjust so that the nut will turn on smoothly with finger pressure. Keep taps and dies clean, oiled, and in a box.

There are many special purpose taps and dies. Fig. 1-22 shows a number of them: A—external rethreading set, B—internal thread restorer, C—thread restorer, D—axle rethreader which is opened up and placed around the good threads and backed off, E and F—nut dies that can be operated with a box end wrench, G and H—spark plug hole thread restorers, very handy for removing rust and carbon, J—combination tap and die set for tube fittings, K—tap and die set with tap handle and die stock.

HACKSAWS

A hacksaw is used to cut tubing, bolts, and other parts. The mechanic should have blades with 18, 24, and 32 teeth per inch. The 18-tooth blade is used for cutting thick metal, the 24-tooth for medium thickness, and the 32-tooth blade for thin sheet metal and tubing. The blades should be of high quality steel as they will cut faster and longer than low quality blades. Fig. 1-23, A, illustrates a typical hacksaw frame. For very thick work, use a 14-tooth blade.

OTHER HACKSAWS

A special hacksaw, termed a "jab saw," will facilitate cutting in tight quarters. A hole saw, driven with an electric drill, is handy for cutting large holes in sheet metal. See B and C in Fig. 1-23.

VISE

A vise suitable for automotive work is pictured in Fig. 1-24. Keep the vise clean. Use copper, lead, or

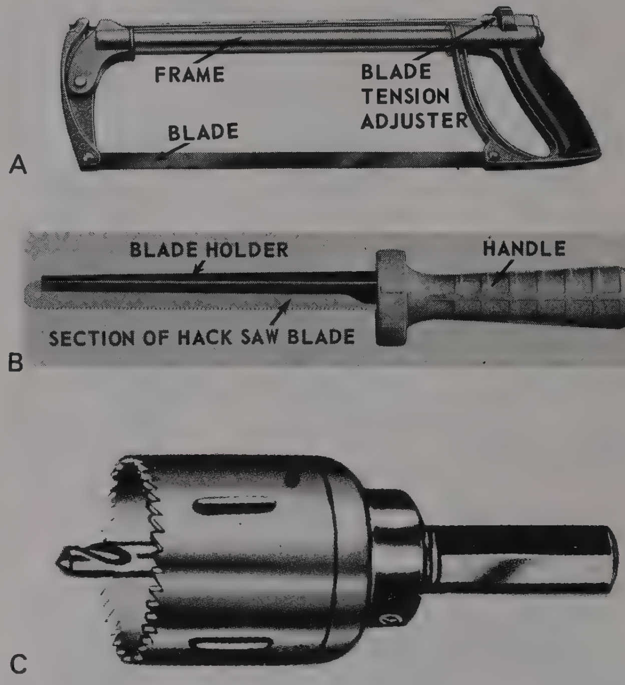


Fig. 1-23. Hacksaws. A—Hacksaw frame. B—Jab saw for tight quarters. C—Hole saw which comes in various diameters. (Owattona Tool Corp., Snap-On Tools)

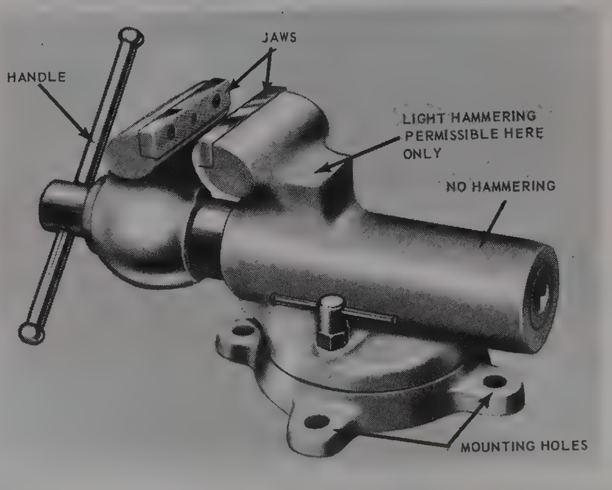


Fig. 1-24. Typical bench vise.

nylon jaw covers for work that may be marred. Oil the working parts and avoid hammering on the handle or on other surfaces.

CLEANING TOOLS

A number of useful cleaning tools are illustrated in Fig. 1-25. Having a selection speeds up cleaning work. The wire wheel and power cleaning brushes are mounted in an electric drill. USE GOGGLES WHEN OPERATING THE WIRE WHEEL AND ALSO WHEN CLEANING WITH CAUSTIC SOLUTIONS! THEY WILL BURN SKIN AND EYES.

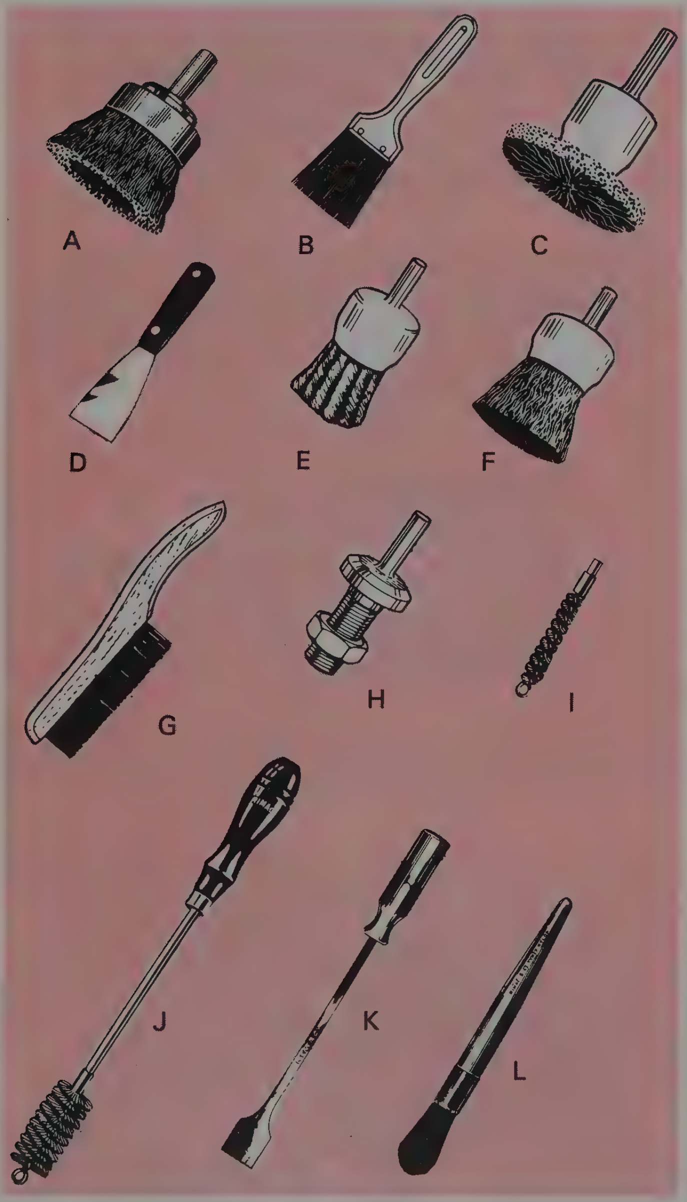


Fig. 1-25. Cleaning tools. A—Hollow carbon brush. B—Wire brush. C—Wire wheel. D—Flexible scraper. E—Twisted strand wire brush. F—Bristle head. G—Hand wire scratch brush. H—Arbor for wire wheel. I—Carbon brush. J—Bristle brush and holder. K—Rigid scraper. L—Cleaning brush with nylon bristles.

SCREWDRIVERS

The mechanic should own several different sizes of screwdrivers, including the standard, Reed & Prince, Phillips, Pozidriv®, and clutch types, Fig. 1-26.

The offset screwdriver, shown in Fig. 1-26, is useful in tight quarters where even a "stubby" cannot be used.

Fig. 1-27 shows the Torx-bit type drivers.

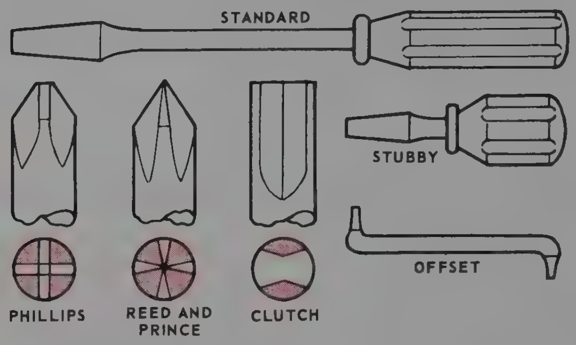


Fig. 1-26. Screwdriver types. When using screwdrivers, select right type and size. A good assortment is essential.

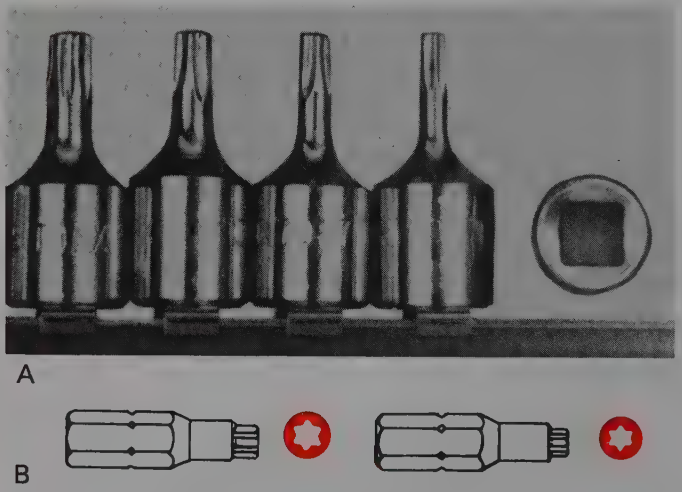


Fig. 1-27. Torx-bit drivers. A—Various size tips are needed. B—Tips designed to be held in a screwdriver type tool. (Vaco Tools)

HANDLING SCREWDRIVERS

Use a screwdriver properly. Avoid prying with or hammering on the screwdriver. Some very large screwdrivers are made so that minor prying and hammering will not harm them, however.

When grinding a new tip on the standard tip screwdriver, maintain the original taper. Do not grind to a sharp point or to a steep taper. This will make the tip twist off or climb out of the slot. Avoid overheating. See Fig. 1-28.

CAUTION! WHEN HOLDING SMALL UNITS IN THE HAND, DO NOT SHOVE DOWN ON THE

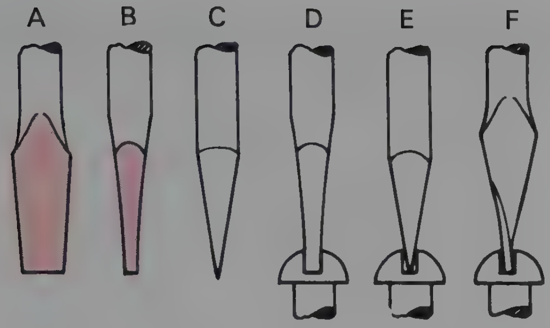


Fig. 1-28. Correct sharpening is important. A and B—Front and side view of correct shape. C—Too steep and sharp. D—Correct taper and size. E—Steep angle will "climb out" of screw slot. F—Screwdriver ground to thin; it will twist off.

SCREWDRIVER HANDLE AS IT MAY SLIP AND PIERCE YOUR HAND. IF WORKING ON ELECTRICAL EQUIPMENT, SHUT OFF THE CURRENT. USE AN INSULATED (FULL LENGTH) SCREWDRIVER AND KEEP YOUR HANDS FREE OF ANY WIRES WHERE IT IS IMPOSSIBLE TO SHUT OFF THE CURRENT. IF YOU MUST WORK AWAY FROM AN OPEN SWITCH, TAG IT SO THAT SOMEONE WILL NOT ACCIDENTALLY TURN IT ON!

PLIERS

Pliers are commonly used for cutting wire, holding parts, crimping connections, and bending cotter pins. The combination slip joint, vise-grip, adjustable rib joint, battery, pump, ignition, long nose, needle nose, diagonal, and side cutter pliers are most often used. Other, more specialized pliers (snap ring, hose-clamp, brake spring) will be covered in later chapters. Avoid cutting hardened objects. Never use pliers to turn nuts, bolts, or tubing fittings, Fig. 1-29.

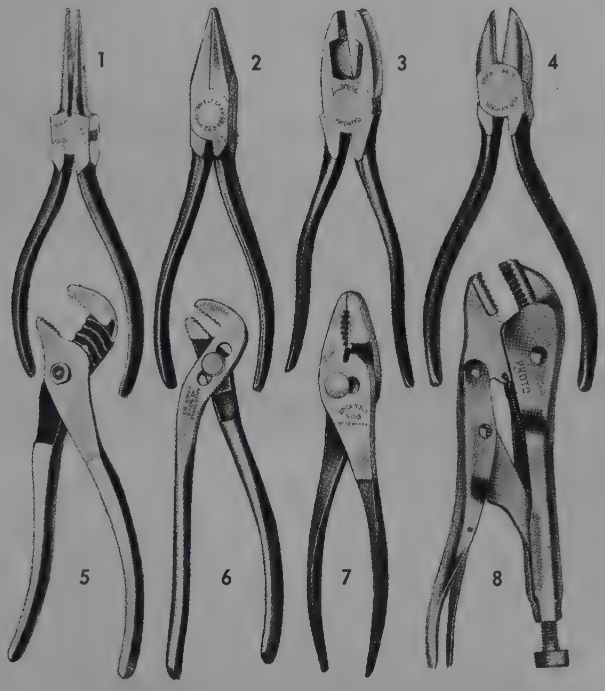


Fig. 1-29. Useful pliers. 1—Needle nose. 2—Chain nose. 3—Electrician. 4—Diagonal. 5—Rib joint. 6—Ignition. 7—Combination slip joint. 8—"Vise-grip" or plier wrench. (Utica and Proto Tools)

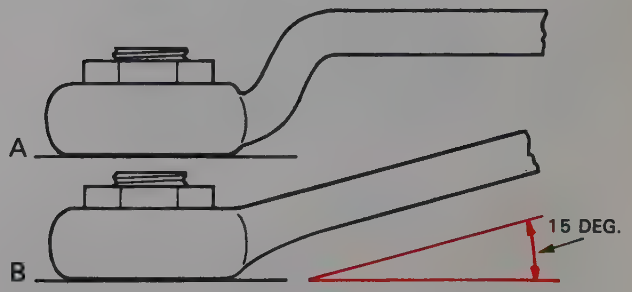


Fig. 1-30. Box end wrenches. A—Double offset. B—15-deg. offset.

BOX END WRENCHES

Box end wrenches are available with 12-point or 6-point openings. The 12-point allows a shorter swing of the tool. The 6-point provides superior holding power. One design uses a double offset to give more handle clearance. Another uses the popular 15-deg. offset. Different lengths, plus a complete range of opening sizes, are needed, Figs. 1-30 and 1-31.

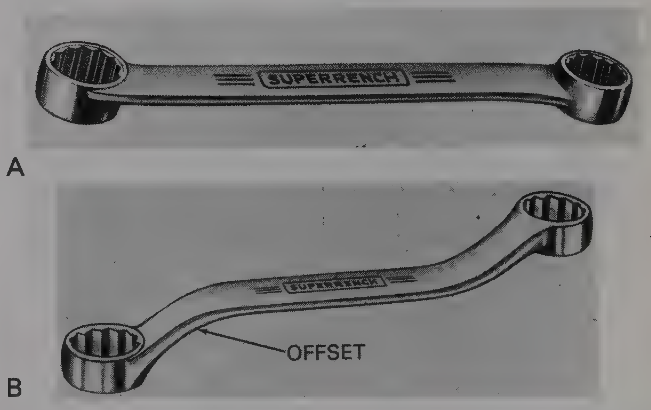


Fig. 1-31. A—Box end wrench. Shown is a 15-deg. offset, short length type. B—Double offset box end wrench.

FLARE NUT WRENCH

The flare nut wrench is quite similar to the box end wrench. It has a section cut out so that it may be slipped around tubing and dropped over the tubing nut. This wrench has either 6-point or 12-point openings. The flare nut wrench is a must for fuel, vacuum, brake, and other fittings. Refer to Fig. 1-32.

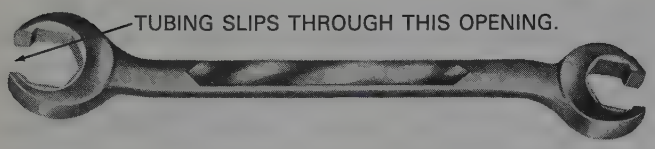


Fig. 1-32. Flare nut wrench. Note opening for tubing. (Owattona Tool Co.)

RATCHET BOX END

This is a ratcheting tool using a box end design. It is fast to use and has many applications, Fig. 1-33.

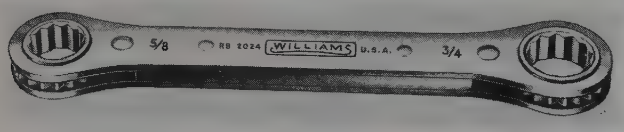


Fig. 1-33. Ratchet box end wrench. To reverse ratchet action, flip wrench over. (J.H. Williams)

OPEN END WRENCH

The open end wrench grasps the nut on only two flats. Unless it fits well, it can slip and round off the nut. There are many places, however, where they may be used. Whenever possible, use a box end or socket instead of an open end.

Open end wrenches have the head set at an angle. In tight quarters, where the handle swing is limited, pull the handle as far as it will go. Then, flip the wrench over and replace it on the nut. By this method, the open end can operate in a swing of 30 deg., Fig. 1-34.

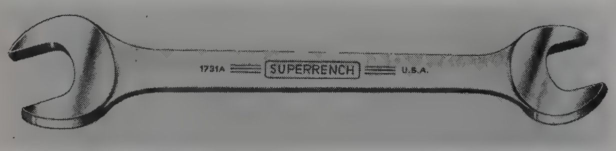


Fig. 1-34. Open end wrench.

COMBINATION BOX AND OPEN END WRENCH

This tool has a box end on one end and an open end on the other. Both ends are of the same size, Fig. 1-35.

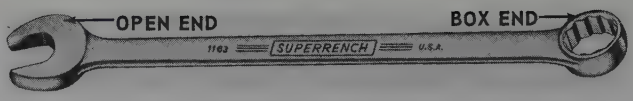


Fig. 1-35. Combination box and open end wrench.

SOCKET WRENCHES

The socket is one of the fastest and most convenient of all the wrenches. Sockets are available in 6-point and 12-point openings and in 1/4, 3/8, 1/2, 3/4 in., and larger drives. Drive size indicates the size of the square driving hole in the base of the socket.

The mechanic should have a 1/4 in. drive for small fasteners, a 3/8 in. drive to handle the medium sizes, and a 1/2 and 3/4 in. drive for the remainder of the work.

Sockets come in two depths: standard and deep. Standard sockets will handle the bulk of the work, while the extra reach of the deep socket is occasionally needed for vacuum switches, oxygen sensors, etc., Fig. 1-36.

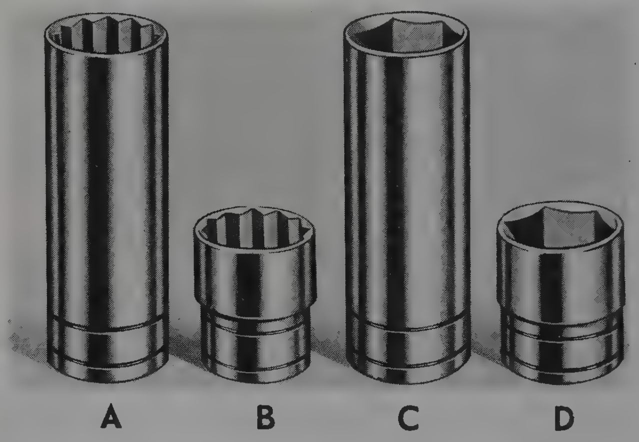


Fig. 1-36. Various sockets. A—12-point deep socket. B—12-point standard socket. C—6-point deep socket. D—6-point standard socket. (Snap-On Tools)

SWIVEL SOCKET

The swivel socket allows the user to turn fasteners at an angle. As a result, it is handy for many jobs, Fig. 1-37.

SOCKET HANDLES

Several different drive handles are used. The speed handle is used whenever possible as it can be turned rapidly. See Fig. 1-38.

Flex handles of different lengths provide heavy turning leverage and may be used at many angles, Fig. 1-39.

The sliding T-handle has some applications and should be included in a socket set, Fig. 1-40.

Spinner handles are used much as screwdrivers and will accept all the socket attachments. See Fig. 1-41.

The ratchet handle allows both heavy turning force and speed. The fastener can be turned in or out by flicking a lever on the ratchet. The ratchet is also useful where a limited swing is necessary, Fig. 1-42.

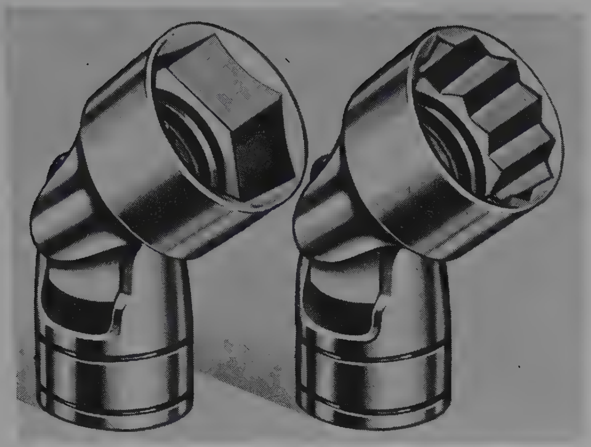


Fig. 1-37. Note difference between 6 and 12-point swivel sockets.

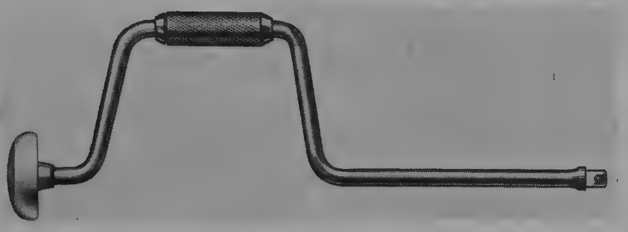


Fig. 1-38. Socket speed handle. (J.H. Williams)

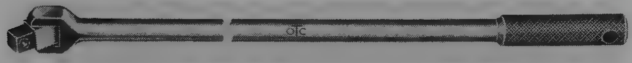


Fig. 1-39. Socket flex handle. (Owattona Tool Corp.)

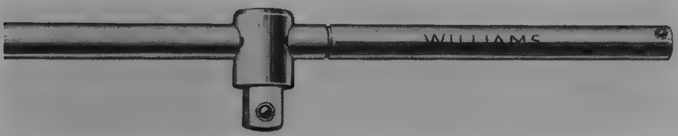


Fig. 1-40. Socket sliding T-handle.

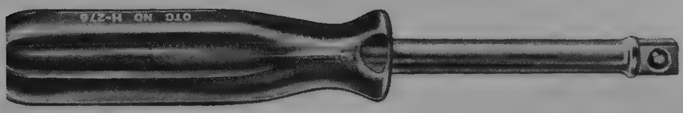


Fig. 1-41. Socket spinner handle.

A ratcheting adapter can be used with a flex handle, T-handle, etc., thus making them quite versatile, Fig. 1-43.

The universal joint will permit driving at different angles with the various socket handles. See Fig. 1-44.

Sockets of one particular drive size can be turned with the handles from another by using an adapter, Fig. 1-45.

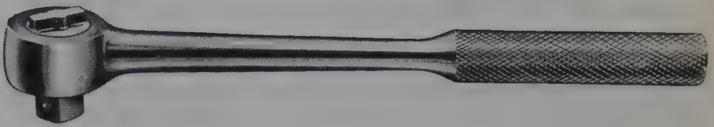


Fig. 1-42. Socket ratchet handle. (Owattona Tool Corp.)

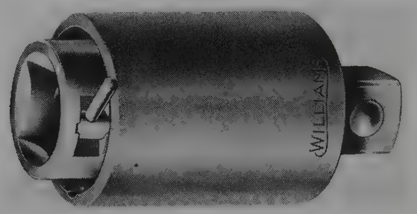


Fig. 1-43. Socket ratcheting adapter. (J.H. Williams)

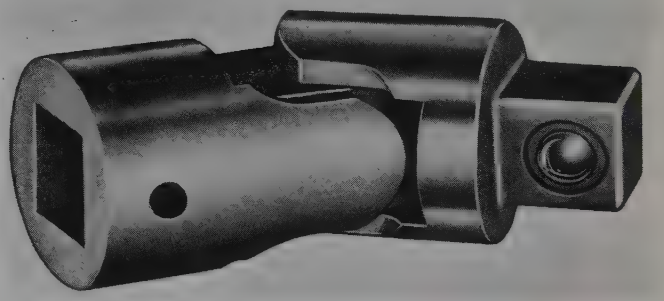


Fig. 1-44. Socket universal joint.

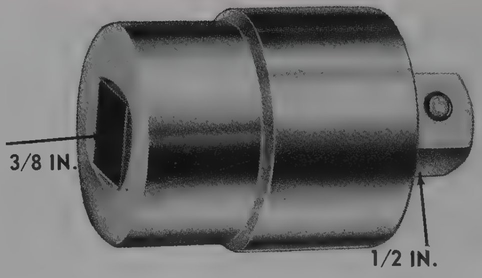


Fig. 1-45. Sockete adapter.

OTHER SOCKET ATTACHMENTS

Screwdriver, drag link, and crowfoot socket attachments are a few of the many offered. Refer to Fig. 1-46.

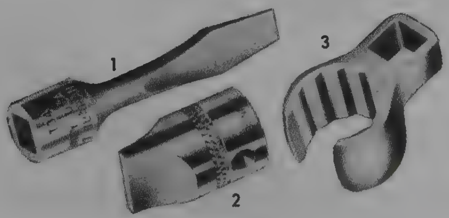


Fig. 1-46. Other socket attachments. 1—Screwdriver. 2—Drag Link. 3—Crowfoot. (Bonney Tools)

SOCKET EXTENSIONS

The long, medium, and short extensions allow the user to extend the reach of the tool. They may be used singly or snapped together if so desired, Fig. 1-47.

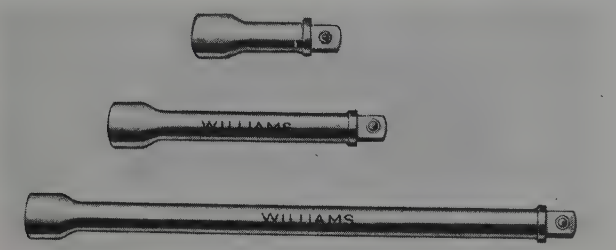


Fig. 1-47. Socket extension bars. (J.H. Williams)

FLEX-HEAD WRENCH

The flex-head wrench is a valuable addition to the tool box. It can be used through various angles and in cramped quarters, Fig. 1-48.

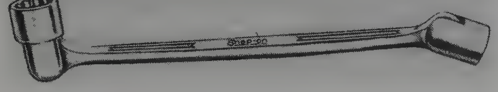


Fig. 1-48. Flex-head wrench. (Snap-On Tools)

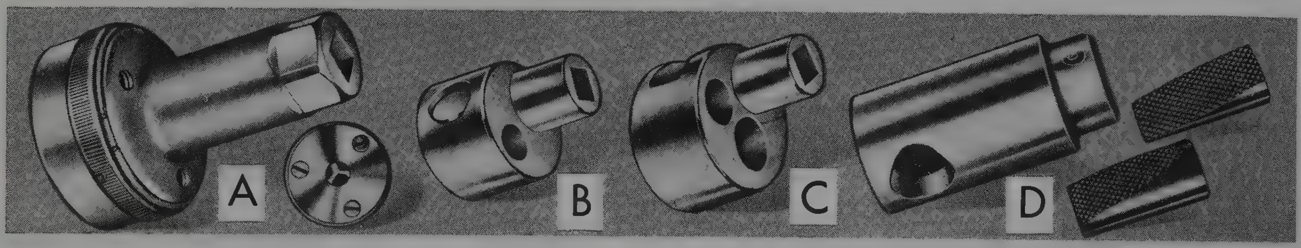


Fig. 1-50. Stud wrench types. A—Three jaw. B—Wedge type similar to Fig. 1-49. C—Rotating lock wheel. D—Wedge type for tight quarters. (Snap-On Tools)

STUD WRENCH

Several types of stud wrenches are manufactured. With any of them, be careful not to damage the threads on the stud. See Figs. 1-49 and 1-50.

EXTRACTORS

Broken screw extractors are often needed to remove the threaded portions of cap screws that break off. One type is shown in Fig. 1-51.

"CRESCENT" OR ADJUSTABLE WRENCH

The adjustable wrench is a useful tool. Its size may be readily changed to that of the fastener. However, it can loosen and slip. When other wrenches are available, use them. Refer to Fig. 1-52.

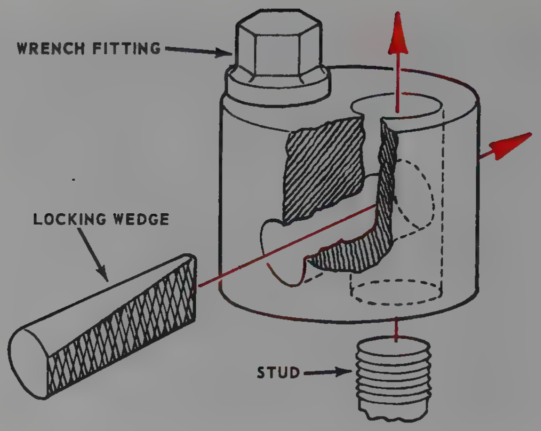


Fig. 1-49. Stud wrench. Wrench is dropped over stud and locking wedge is shoved in bore until it contacts stud. When wrench is turned, wedge jams against stud. To remove stud, insert wedge as shown. To install stud, insert wedge from opposite side.

PIPE WRENCHES

The pipe wrench is used to grasp irregular or round surfaces. It provides great gripping power. Both inside and outside pipe wrenches should be available. Look at Fig. 1-53.

CHAIN WRENCH

The chain wrench is extremely handy for holding or turning large, irregular-shaped objects, Fig. 1-54. Some employ a fabric strap in place of the chain. These would be termed STRAP WRENCHES.

ALLEN AND FLUTED WRENCHES

These wrenches are usually used to turn setscrews and cap screws. See Fig. 1-55.

BEWARE! WHEN USING ANY WRENCH, MAKE CERTAIN THE WRENCH IS THE CORRECT SIZE AND IS SECURELY ENGAGED. PULL; DO NOT PUSH. IF PUSHING IS AB-

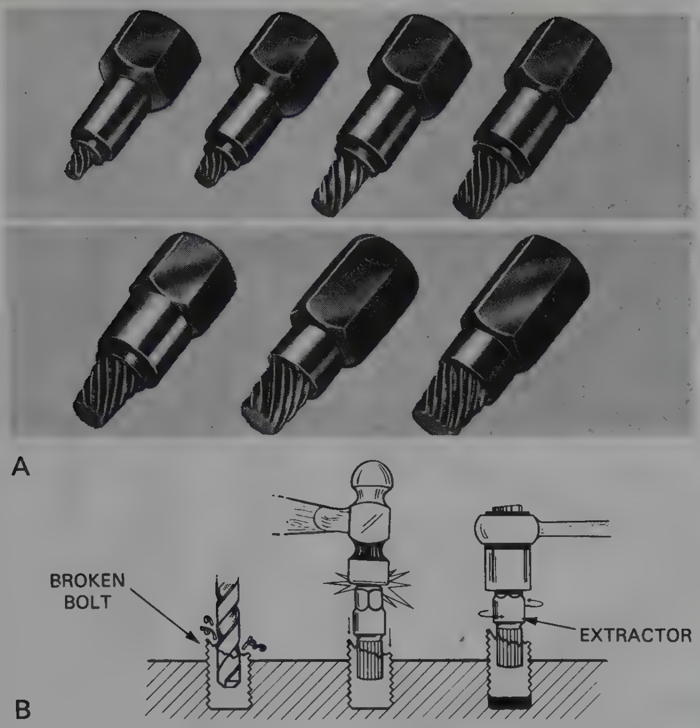

A
BROKEN BOLT
EXTRACTOR
B

Fig. 1-51. A—Screw extractors are available in various sizes. B—Extractor being used to remove broken bolt. (Snap-On Tools & Lisle)

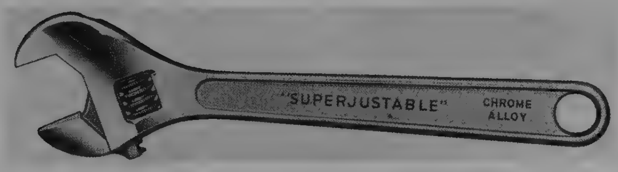

"SUPERJUSTABLE"
CHROME ALLOY

Fig. 1-52. Adjustable wrench.

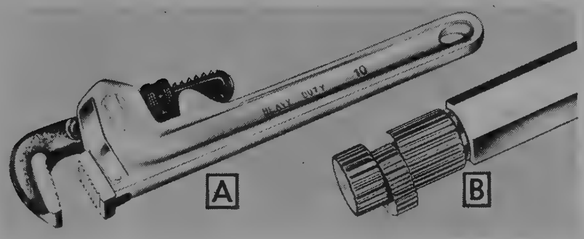

HEAVY DUTY
10
A
B

Fig. 1-53. Pipe wrenches. A—Outside pipe wrench. B—Inside pipe wrench.

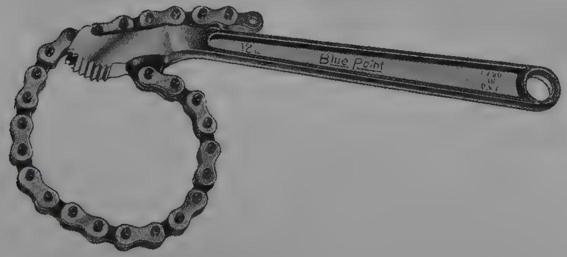


Fig. 1-54. Chain wrench. This wrench is very handy for turning large, irregular shaped objects. (Blue Point)

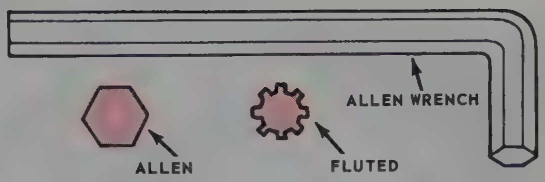

ALLEN WRENCH
ALLEN
FLUTED

Fig. 1-55. Allen and fluted wrenches.

SOLUTELY NECESSARY, OPEN THE HAND AND PUSH WITH THE PALM. BE CAREFUL, IF A WRENCH SLIPS, YOU CAN BE SERIOUSLY CUT!

PROBING TOOLS

Mechanical fingers, extension magnets, and mirror devices help the mechanic to retrieve parts and to see in blind areas, Fig. 1-56.

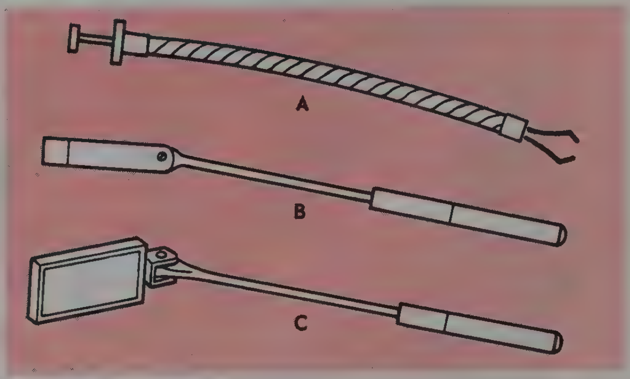


Fig. 1-56. Probing tools. A—Mechanical finger pickup. B—Telescoping magnet. C—Telescoping mirror.

POWER OR IMPACT WRENCHES

An electric or pneumatic (air) impact wrench, used in conjunction with sockets, speeds up the job. Most shops commonly use them, Fig. 1-57.

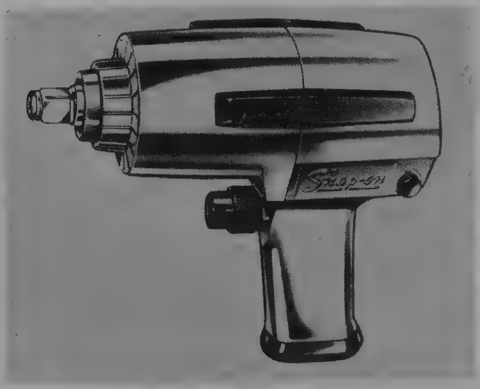


Fig. 1-57. An air operated impact wrench. Impact wrenches are fast and efficient. (Snap-On Tools)

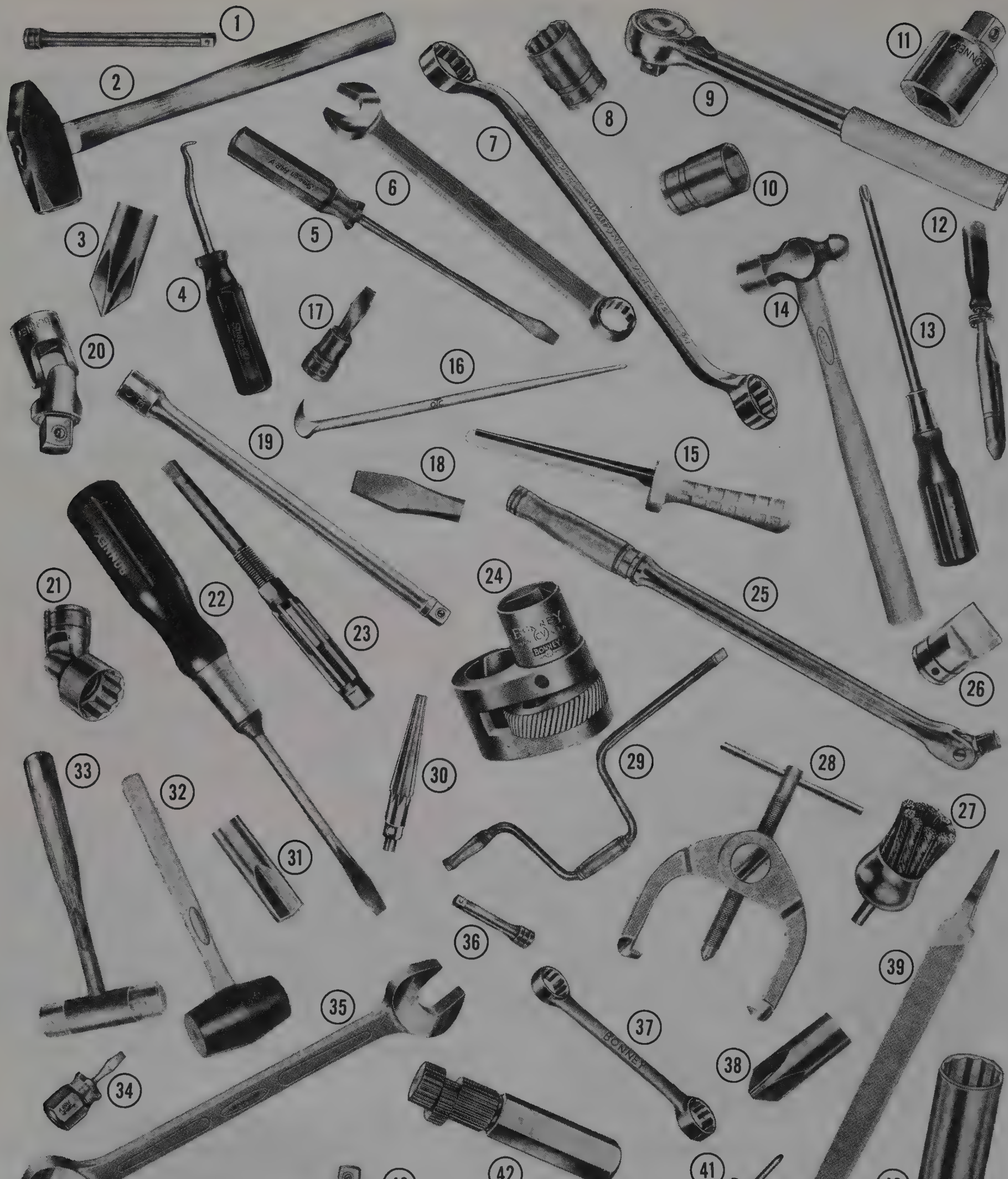
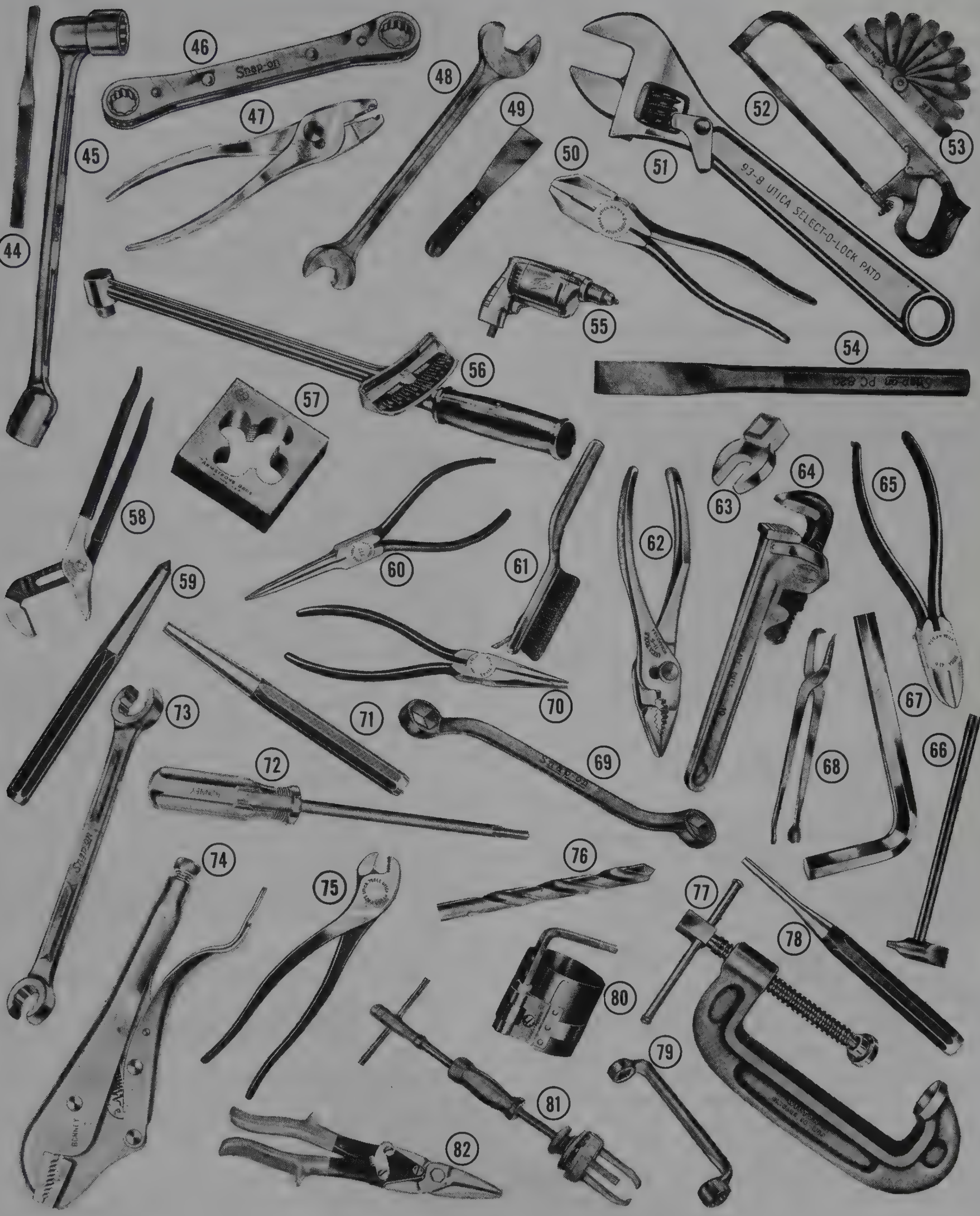


Fig. 1-58. 1—Medium length socket extension. 2—Cross peen hammer. 3—Reed and Prince screwdriver head. 4—Cotter pin puller. 5—Standard screwdriver. 6—Combination box and open end. 7—Standard length, double offset box end. 8—Regular 12-point socket. 9—Socket ratchet handle. 10—Regular 6-point socket. 11—Socket drive adapter 1/2 in. to 3/8 in. 12—Soldering iron. 13—Phillips head screwdriver. 14—Ball peen hammer. 15—Jab saw. 16—Aligning bar with roller head. 17—Screwdriver socket. 18—Standard screwdriver tip. 19—Long socket extension. 20—Socket universal drive joint. 21—12-point flex socket. 22—Standard screwdriver. 23—Adjustable reamer. 24—Stud wrench. 25—Socket flex handle. 26—Drag link socket. 27—Small wire carbon brush. 28—Gear puller. 29—Socket speed handle. 30—Tapered reamer. 31—Clutch type screwdriver tip. 32—Rubber mallet. 33—Plastic tip hammer. 34—Stubby regular tip screwdriver. 35—Open end wrench. 36—Short socket extension. 37—Short 15-deg. box end wrench. 38—Phillips screwdriver tip. 39—Flat mill file. 40—12-point deep socket. 41—Stubby Phillips screwdriver. 42—Internal pipe wrench. 43—Socket sliding T-handle. (Bonney, Snap-On, Owattona, Utica, Wilton, Proto, and Armstrong Tools)


46
Snap-on
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93-8 UTICA SELECT-O-LOCK PATD
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PC 820
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Fig. 1-59. 44—Point file. 45—Flex socket. 46—Ratchet box end. 47—Hose clamp plier. 48—Ratchet open end. 49—Carbon scraper. 50—Electrician plier. 51—Adjustable wrench. 52—Hacksaw frame. 53—Feeler gauge. 54—Cold chisel. 55—1/4 in. electric drill. 56—Torque wrench. 57—Pipe die. 58—Rib joint plier. 59—Center punch. 60—Needle nose plier. 61—Cleaning brush. 62—Slip joint plier. 63—Crowfoot attachment. 64—Pipe wrench. 65—Diagonal plier. 66—Offset screwdriver. 67—Allen wrench. 68—Brake spring plier. 69—6-point box end. 70—Chain nose plier. 71—Starting punch. 72—Clutch tip screwdriver. 73—12-point tubing wrench. 74—Vise grip plier. 75—Battery plier. 76—Twist drill. 77—C-clamp. 78—Drift punch. 79—Cylinder head wrench. 80—Ring compressor. 81—Slide hammer puller. 82—Sheet metal snips.
(Bonney, Snap-On, Owattona, Utica, Wilton, Proto, Armstrong, Williams, Thor and Sturtevant Tools)

OTHERS TO FOLLOW

As mentioned, many other more specialized tools will be discussed in this text. When you come across one, pay particular attention to the name and how it is used, Figs. 1-58 and 1-59. Many jobs can be made either time consuming and difficult or fast and easy, depending on an intelligent selection of tools. REMEMBER: PROPER TOOL SELECTION AND USE IS VERY IMPORTANT - LEARN ALL YOU CAN ABOUT THEM!

SUGGESTED ACTIVITIES

Write to tool manufacturers and ask for a copy of their tool catalog, and any informative tool brochures they may offer. You may find their names and addresses by looking in automotive trade papers.

After you have received your material, study it carefully. Learn the names and suggested uses of as many tools as you can. Flick through the pages and see how many you can identify correctly. You will be amazed at the number of automotive tools that are available.

MARK YOUR TOOLS

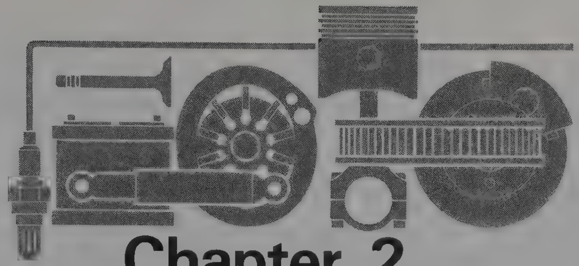
As you procure tools, scribe your name on them. An electric marking pencil or a vibrating tool will do a good job. Mark the tools in an area that will be difficult to grind off.

KNOW THESE TERMS

Chisel, Punch, File, Grinder, Reamer, Tap, Die, Scraper, Phillips, Vise grip, Box end, Open end, Combination wrench, 6-point, 12-point, Universal joint, Speed handle, Flex handle, Ratchet handle, Extension, Impact wrench, Torx-bit.

QUIZ - Chapter 1

1. Chisels, files, drills, and similar tools are very hard and as a result, can all be piled together for storage. True or False?
2. Present day tools are all rustproof. True or False?
3. Explain how YOU will store YOUR tools. clean and orderly
4. Three types of useful hammers would be the ball pin, plastic, and the lead press.
5. Give two safety precautions for hammers. handle tight in the head and clean dry
6. A diamond point chisel is ideal for cutting off rivets. True or False?
7. Name three other important chisels. half round - cape flat
8. For heavy hammering, hold the chisel very tightly with the hand. True or False?
9. Drawing the temper from a tool will soften it. True or False?
10. A pin punch is ideal to drive a rivet from a hole. True or False?
11. Before drilling a hole, Center punch the spot where the drill will start.
12. When grinding tools, quench coldwater often to prevent overheating.
13. Name four file shapes used by the mechanic.
14. A file with one row of parallel cutting edges is known as a Single cut Mile file.
15. Keep files lightly oiled. True or False?
16. Would you use a BASTARD, SECOND CUT, or SMOOTH CUT to rough file a piece of aluminum?
17. From a safety standpoint, why should a file always be used with a handle?
18. A wire brush is used to clean files.
19. When grinding, never let the tool rest get close to the wheel. True or False?
20. Give ten important safety rules for grinders.
21. Better quality drills are made of high Speed Steel.
22. What are the drill lip angles for general purpose cutting? 12 degree
23. Give five important safety rules for electric drills.
24. A reamer should remove about .001 to .002" of stock each cut.
25. Always turn a reamer in a Clockwise direction.
26. Dies are used to cut external threads.
27. Name four kinds of taps.
28. Referring to your tap drill size chart in this chapter, what is the correct tap drill size for a cap screw 5/8 in. diameter with 11 threads per inch?
29. An 18-tooth hacksaw blade is excellent for cutting tubing. True or False?
30. The teeth on a hacksaw blade should always face the handle. True or False?
31. Name four cleaning tools.
32. What five kinds of screwdrivers would you need?
33. Pliers are useful to tighten tubing fittings. True or False?
34. Name six kinds of pliers.
35. Describe briefly a box end, open end, and adjustable wrench.
36. Flare nut wrenches should be used on fuel vocumins brake fittings.
37. What advantage does a 6-point opening have over a 12-point? The 12-point over the 6-point?
38. Sockets are either of the __________ or the __________ length.
39. Name five socket handles.
40. An impact wrench will speed up your work a considerable amount. True or False?
41. How many of the tools can you identify in Figs. 1-58 and 1-59? 50%
42. In addition to the conventional pipe wrench, a chain wrench is handy for turning irregular shaped objects.
43. Broken sections of cap screws can often be removed by using a Extractor.



Chapter 2

PRECISION MEASURING TOOLS

After studying this chapter, you will be able to:
- ☐ Identify common measuring tools.
- ☐ Select the appropriate measuring tool for the job.
- ☐ Use precision measuring tools.
- ☐ Properly maintain precision measuring tools.

The auto mechanic must be thoroughly familiar with the precision measuring tools used in the trade. Many jobs involve checking sizes, clearances, and alignments.

A careless or inaccurate measurement can be costly, both in money and customer relations—to say nothing of damaging the mechanic's reputation.

QUALITY TOOLS

When selecting measuring tools that will be used for a period of years, it pays to buy top quality tools. The initial cost will obviously be higher. However, considering the importance of accuracy, the longer life span of superior tools easily justifies the extra cost.

STORAGE

It is advisable to keep your measuring tools in a protective case. Also, keep them in an area that will not be subjected to excessive moisture or heavy usage. See Fig. 2-1.

After each use, wipe the tool down with a lightly oiled, lint-free, clean cloth. Never dip a precision measuring tool in solvent (unless it is being completely dismantled). Do not use an air hose for cleaning precision measuring tools.

HANDLING

When using a measuring tool, place it in a clean area where it will not fall or be struck by other tools. Never pry, hammer, or force the tools. REMEMBER: They are PRECISION tools—keep them that way!

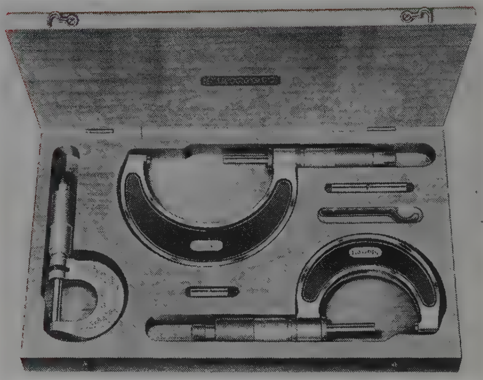


Fig. 2-1. This micrometer case provides excellent protection for tools. (L. S. Starrett)

CHECK FOR ACCURACY

It is good practice to occasionally check precision tools for accuracy. They may be checked against a tool of known accuracy or by using special gauges.

If a tool is accidentally dropped or struck by some object, immediately check it for accuracy. Adjustments for wear or very minor damage are provided on many measuring tools. Follow the manufacturer's instructions.

OUTSIDE MICROMETER

The outside micrometer (mike) is used to check the diameter of pistons, pins, crankshafts, and other machined parts. The most commonly used micrometer reads in one thousandths of an inch. With this micrometer, it is easy to estimate as close as one-quarter thousandth.

Some micrometers can measure to within one tenthousandth of an inch. This type uses a vernier scale.

A cutaway view of a typical outside micrometer is shown in Fig. 2-2. Learn the names of the parts and their relationship to the operation of the tool.

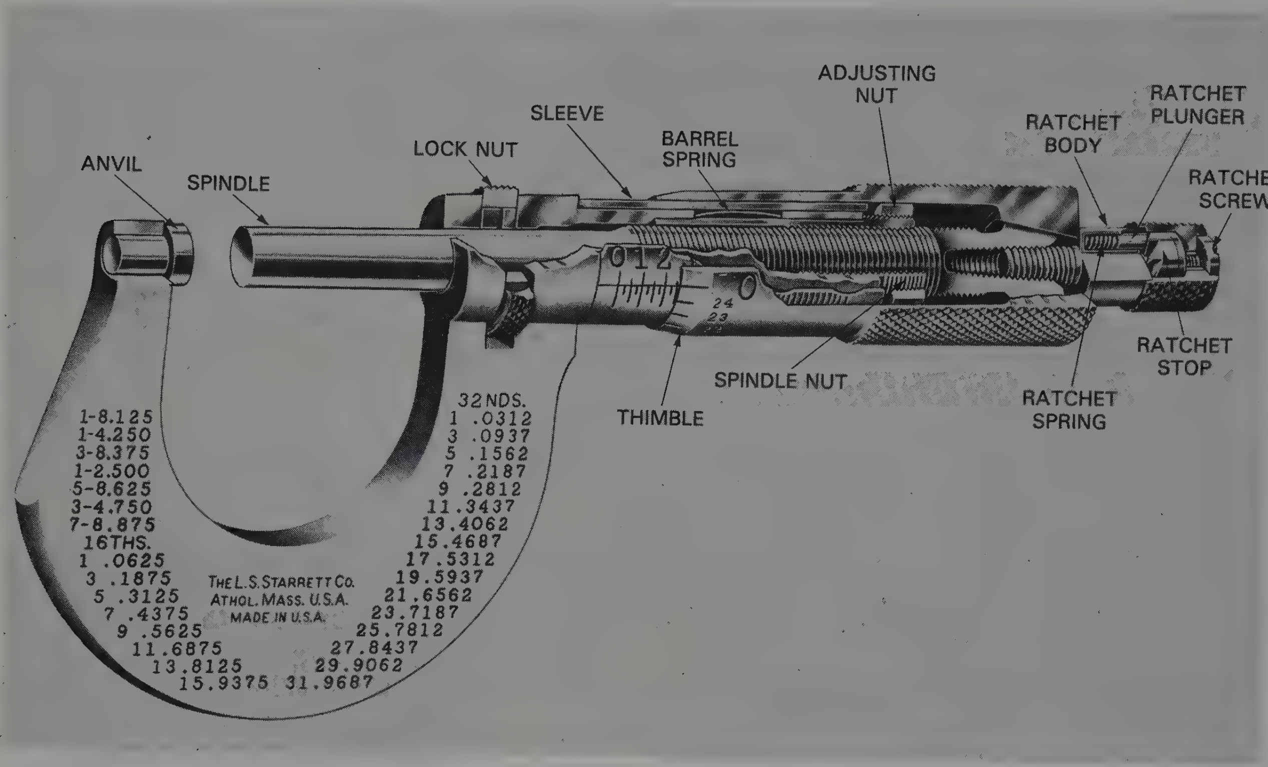

ANVIL
SPINDLE
LOCK NUT
SLEEVE
BARREL SPRING
ADJUSTING NUT
RATCHET BODY
RATCHET PLUNGER
RATCHET SCREW
RATCHET STOP
RATCHET SPRING
SPINDLE NUT
THIMBLE
1-8.125
1-4.250
3-8.375
1-2.500
5-8.625
3-4.750
7-8.875
16THS.
1 .0625
3 .1875
5 .3125
7 .4375
9 .5625
11 .6875
13 .8125
15 .9375
32NDS.
1 .0312
3 .0937
5 .1562
7 .2187
9 .2812
11 .3437
13 .4062
15 .4687
17 .5312
19 .5937
21 .6562
23 .7187
25 .7812
27 .8437
29 .9062
31 .9687
THE L. S. STARRETT CO.
ATHOL. MASS. U.S.A.
MADE IN U.S.A.

Fig. 2-2. Cutaway view of an outside micrometer. Learn the names of the various parts.

MICROMETER RANGE

Each micrometer is designed to produce readings over a range of one full inch. Ideally, the auto mechanic should obtain a set of six micrometers covering sizes 0-1 in., 1-2 in., 2-3 in., 3-4 in., 4-5 in., and 5-6 in. Fig. 2-3 shows a set of twelve micrometers covering 0-12 in.

It would be less expensive to purchase only two micrometers, a 0-4 in. and a 4-6 in., both with interchangeable anvils. However, the multirange micrometer is more bulky and is less convenient to use, Fig. 2-4.

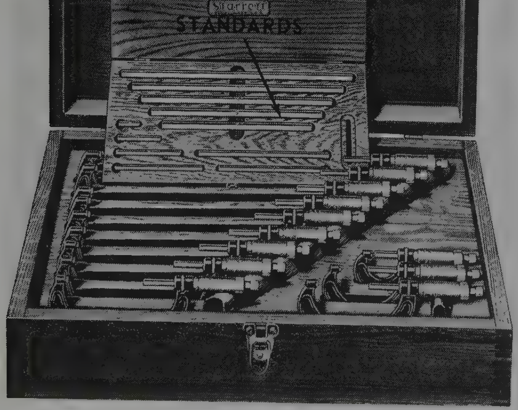

Starrett
STANDARDS

Fig. 2-3. Cased set of twelve outside micrometers. Note box of standards for checking accuracy of each "mike."

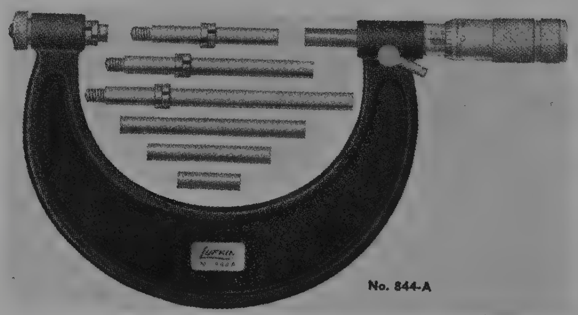


Fig. 2-4. A multiple range micrometer. By using proper anvil, this micrometer covers a range of from 0 in. to 4 in. (Lufkin)

READING THE MICROMETER

Micrometers are made so that every turn of the thimble will move the spindle .025 in. You will notice that the sleeve is marked with a series of lines. Each of these lines represents .025. Every fourth one of these .025 markings is marked 1, 2, 3, 4, 5, 6, 7, 8, or 9. These sleeve numbers indicate .100, .200, .300, etc., (one-hundred thousandths, etc.). The micrometer sleeve then is marked out for one inch in .025 (twenty-five thousandths inch) markings. They will read from .000 to 1.000 (zero to one inch).

The tapered end of the thimble has twenty-five lines marked around it. They will read 0, 1, 2, 3, 4, up to

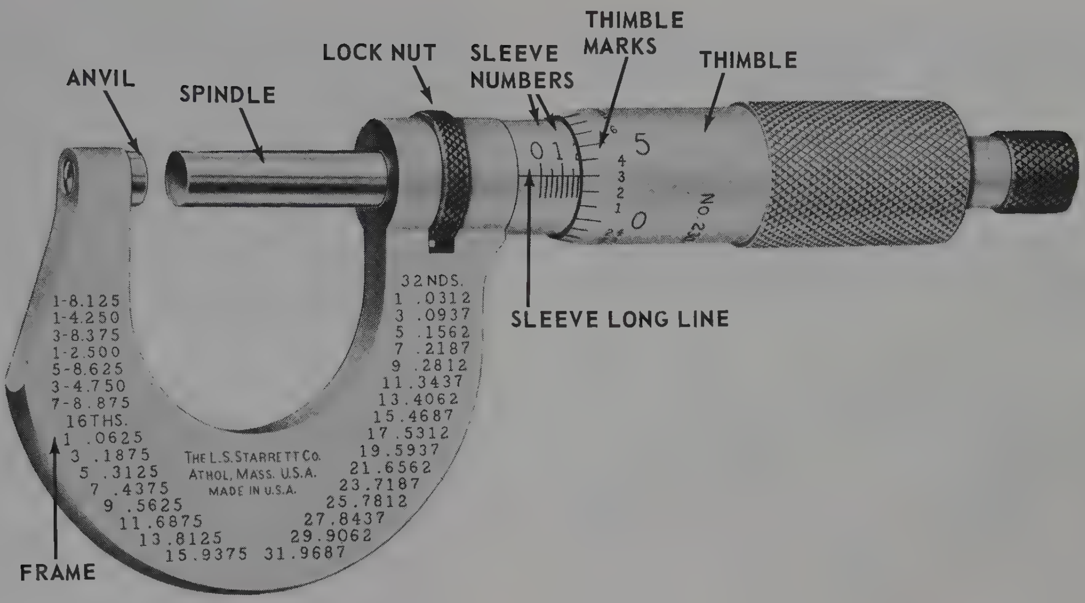

THIMBLE MARKS
LOCK NUT
SLEEVE NUMBERS
THIMBLE
ANVIL
SPINDLE
SLEEVE LONG LINE
FRAME
0 1
5
4
3
2
1
0
NO 2
1-8.125
1-4.250
3-8.375
1-2.500
5-8.625
3-4.750
7-8.875
16THS.
1 .0625
3 .1875
5 .3125
7 .4375
9 .5625
11 .6875
13 .8125
15 .9375
32NDS.
1 .0312
3 .0937
5 .1562
7 .2187
9 .2812
11 .3437
13 .4062
15 .4687
17 .5312
19 .5937
21 .6562
23 .7187
25 .7812
27 .8437
29 .9062
31 .9687
THE L.S. STARRETT Co.
ATHOL, MASS. U.S.A.
MADE IN U.S.A.

Fig. 2-5. A 0-1 in. outside micrometer. Study markings and part names.

25. In that one complete turn of the thimble moves the thimble edge exactly .025, or one mark on the sleeve, the distance between marks is determined by reading the thimble line even with the long line drawn the length of the sleeve markings. Each line on the thimble edge represents .001 (one thousandth of an inch), Fig. 2-5.

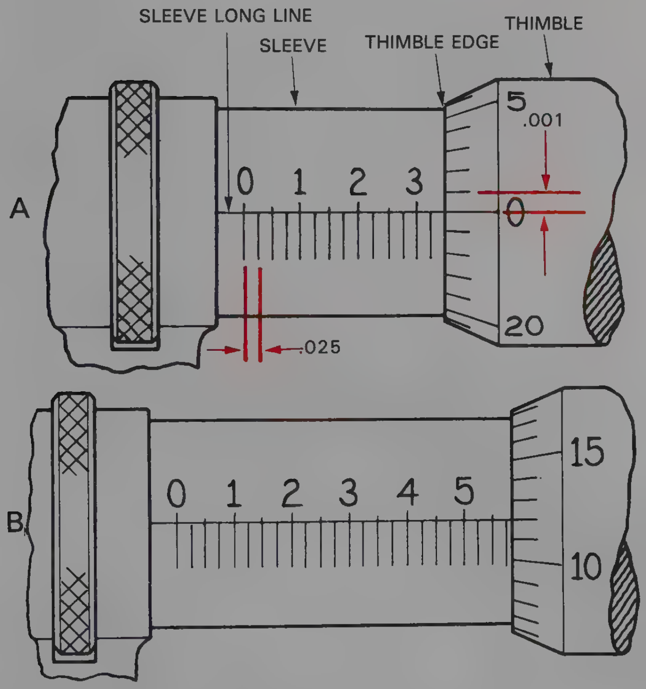

SLEEVE LONG LINE
SLEEVE
THIMBLE EDGE
THIMBLE
A
0 1 2 3
5
.001
0
20
.025
B
0 1 2 3 4 5
15
10

Fig. 2-6. Study numbering system used with an outside micrometer. A—Thimble edge has moved across sleeve up to 3 (.300), plus two more sleeve marks (.050). The thimble 0 mark is in line with the sleeve long line so the reading is .300 + .050 + 0 = .350. B—Thimble edge has moved up to the 5 (.500) plus three more sleeve marks (.075) plus 12 thimble marks (.012) resulting in a total reading of .587.

Look at the markings on the micrometer section in Fig. 2-6, A. How many numbers are visible on the sleeve? There are three. This 3 indicates that the mike is open at least .300 (three-hundred thousandths of an inch). You can see that the thimble edge is actually past the .300 but not to the .400 mark. By careful study, you will see that the thimble edge has moved exactly two additional marks past the .300. This means that the thimble edge is lined up two marks past the .300. As each sleeve mark represents .025, it is obvious that the edge is actually stopped at .300 plus .050, or .350 (three-hundred and fifty thousandths of an inch). Since the thimble edge 0 marking is aligned with the long sleeve line, the mike is set exactly on .350. The reading then, if this were a one inch mike, would be .350. If this were a 2-3 in. mike, the actual reading would be two inches plus .350 or 2.350.

In Fig. 2-6, B the micrometer has been opened to a wider measurement. You will see that the thimble edge is no longer on a sleeve marking but is somewhere in between.

How many numbers are visible on the sleeve? There are five or .500 (five-hundred thousandths). The thimble edge has moved three marks or .075 past the .500 mark. This makes a total of .575. The thimble edge has moved past the third mark. In that the fourth mark is not visible, we know it is somewhere between the third and fourth mark.

By examining the thimble edge marks, Fig. 2-6, B, you will see that the twelfth mark is aligned with the sleeve long line. This means the thimble edge has moved twelve thimble marks past the third sleeve mark. In that each thimble mark equals .001 (one thousandth of an inch), the thimble has actually moved .012 (twelve thousandths of an inch) past the third sleeve mark.

Your reading then would be .500 (largest sleeve number visible) PLUS .075 (three sleeve marks past sleeve number) PLUS .012 (twelve thimble marks past the third sleeve mark), making a total reading of .587 (five-hundred and eighty-seven thousandths of an inch). If this were a 3-4 in. micrometer, the actual measurement would be 3.587.

Study the readings shown in Fig. 2-7. Compare your answers with those shown. Make your readings in four steps. See Fig. 2-8.

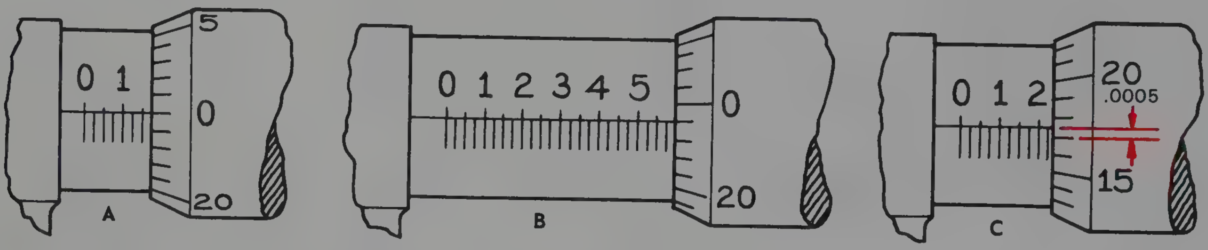


Fig. 2-7. A = .175, B = .599, C = .242 1/2 or .2425. Note that in C, the fraction in one-thousandth is estimated as indicated by the thimble mark.

1. Read the largest sleeve number that is visible—each one indicates .100.
2. Count the number of full sleeve marks past this number—each one indicates .025.
3. Count the number of thimble marks past this last sleeve number. Each one indicates .001. If the thimble marks are not quite aligned with the sleeve long line, estimate the fraction of a mark.
4. Add the readings in steps 1, 2, and 3. The total is the correct micrometer reading. Add this reading to the starting size of the micrometer being used. If the mike range was 1-2 in., add the total reading to 1.000 (one inch), Fig. 2-8.

READING A MICROMETER GRADUATED IN TEN THOUSANDTHS OF AN INCH

The same reading technique is used to read this type of micrometer. Instead of estimating fractions of a thousandth between thimble marks, a VERNIER scale on the sleeve is used. This makes it possible to accurately divide each thousandth into ten parts or one ten-thousandth of an inch.

The vernier consists of eleven thin lines scribed parallel to the sleeve long line. They are marked 0-10. When the thimble marks do not fall in line with the long sleeve line, indicating a fraction of one thousandth inch, carefully examine the vernier lines. One of the vernier lines will be aligned with one of the thimble marks. When you have discovered the specific vernier line that is aligned, the number of that vernier line indicates the number of ten-thousandth to be added to your initial thimble reading. Look at Fig. 2-9.

Examine the readings shown in Fig. 2-10. In both instances a fraction of a thousandth is obvious by examining the thimble marks. By checking the vernier, you can see that one of the vernier lines is in alignment with a thimble mark, thus indicating the number of ten-thousandth over the thimble thousandth reading. Compare your readings with those shown. See Fig. 2-10.

METRIC MICROMETER

The metric micrometer (either inside or outside) closely resembles the standard type. The basic differences between them are the thimble and sleeve markings. The metric micrometer is marked to measure hundredths of a millimetre instead of thousandths of an inch.

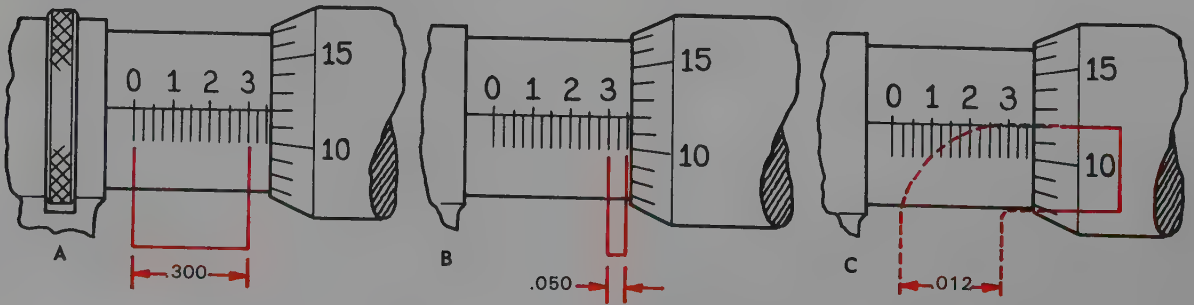


Fig. 2-8. Three steps in reading the micrometer. First reading in A = .300, second reading in B = .050, third reading in C = .012 = a total reading of .362 (Three hundred and sixty-two thousandths).

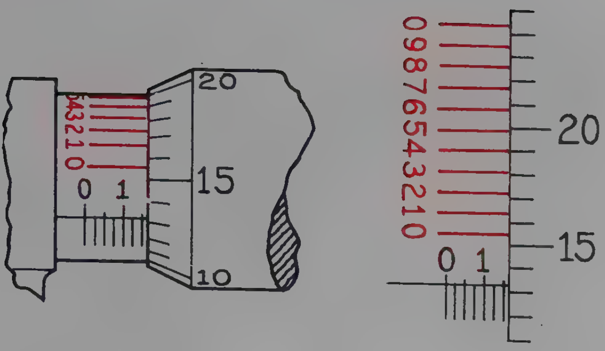


Fig. 2-9. Vernier lines are shown in color. Note that vernier line No. 4 is only one exactly inline with a thimble mark. Your reading would then be .100 + .050 + .013 + .0004 (four ten-thousandths) = .1634.

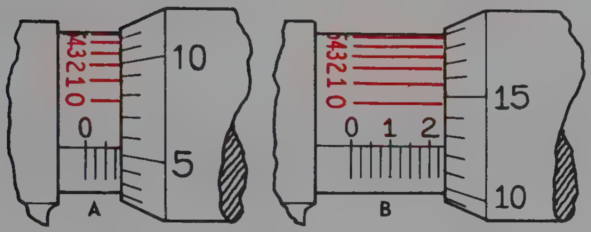


Fig. 2-10. A—Vernier line No. 5 is aligned with a thimble mark; reading would be .075 + .005 + .0005 = .0805. B—Vernier line No. 4 is aligned; reading would be .200 + .025 + .0004 =.2374.

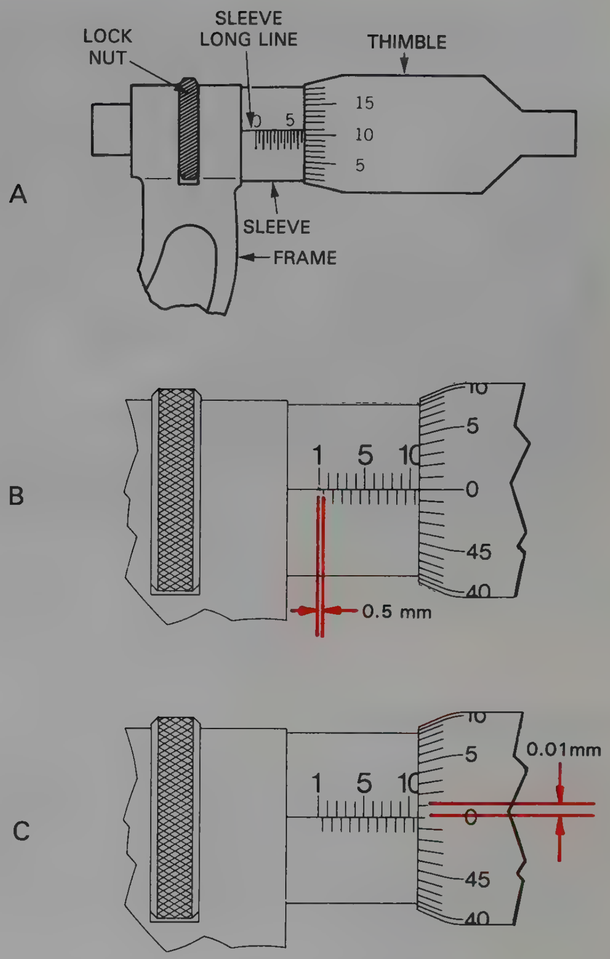


Fig. 2-11. Typical outside metric micrometer. Notice that this mike requires two full revolutions of the thimble to equal one millimetre. (TRW, Deere & Co.)

Each individual line on the sleeve equals 0.5 mm. Every thimble line equals 0.01 mm. For every two full revolutions of the thimble, the spindle is advanced 1.00 mm. See Fig. 2-11.

To obtain a reading, follow the next four steps using micrometer B in Fig. 2-11 as an example.

1. Highest line showing on sleeve (10) = 10.00 mm
2. Number of lines showing on the sleeve past highest figure (1)............ = 0.5 mm
3. Line on thimble aligning with the sleeve long line (datum line) (0)..... = 0.0 mm
4. Add numbers to obtain measurement... 10.5 mm

What reading do you get for A, Fig. 2-11?

WHEN USING ANY MEASURING TOOL

Always thoroughly clean the work to be measured. This assures accurate readings and reduces wear on the working tips of the tool.

USING OUTSIDE MICROMETER

When measuring small objects, grasp the micrometer in the right hand. At the same time, insert the object to be measured between the anvil and spindle. While holding the work against the anvil, turn the thimble with the thumb and forefinger until the spindle engages the object. Do not clamp the micrometer tight. Use only enough pressure on the thimble to cause the work to JUST FIT between the anvil and spindle. Slip the object in and out of the micrometer while giving the thimble a final adjustment. The work must slip through the micrometer with a VERY LIGHT FORCE.

When satisfied that your adjustment is correct, read the micrometer setting. BE CAREFUL THAT YOU DO NOT MOVE THE ADJUSTMENT, Fig. 2-12.

To measure larger objects, grasp the frame of the micrometer and slip the micrometer over the work while adjusting the thimble. Slip the mike back and forth until very light resistance is felt, Fig. 2-13.

Some micrometers have a ratchet clutch knob on the end of the thimble. It allows the user to bring the spindle down against the work with the same amount of tension each time.

As the micrometer is slipped back and forth over the work, it should be rocked from side to side slightly. This will make certain the spindle cannot be closed an additional amount, Fig. 2-14.

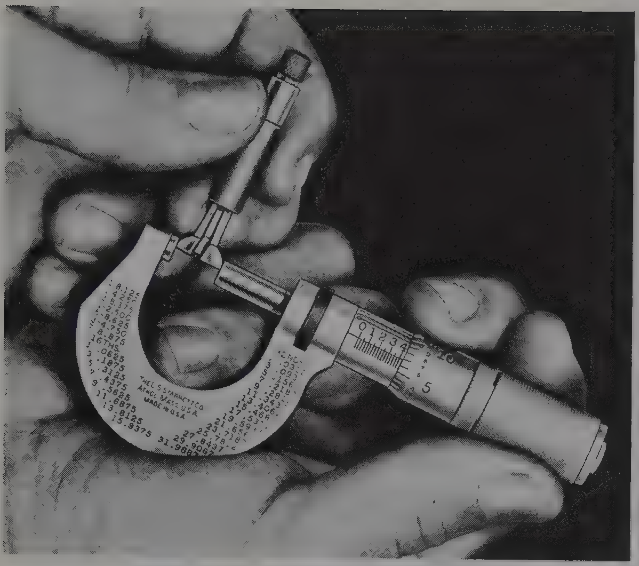


Fig. 2-12. Miking a small hole gauge. Heel of hand supports micrometer frame while thumb and forefinger turn thimble. (L. S. Starrett)

DIGITAL MICROMETERS

The digital micrometer provides precise measurement readings at a glance. It is similar to a standard micrometer, but the readings appear in a window instead of on the hub and thimble, Fig. 2-15. Some micrometers provide both standard and digital readings.

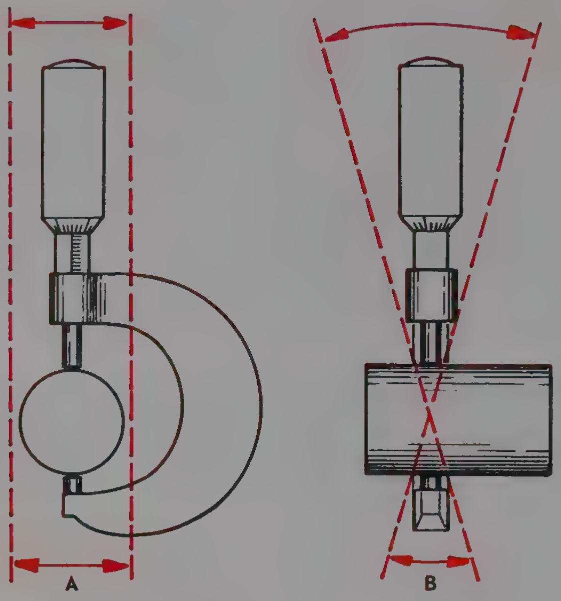


Fig. 2-14. A—Micrometer is slipped back and forth over object. B—Micrometer is rocked from side to side to make certain smallest diameter is found. Rocking is actually very slight.

HANDLE THE MICROMETER WITH CARE. NEVER STORE A MIKE WITH THE ANVIL AND SPINDLE TIP TOUCHING (this encourages rusting between tips). CLEAN YOUR WORK BEFORE MEASURING.

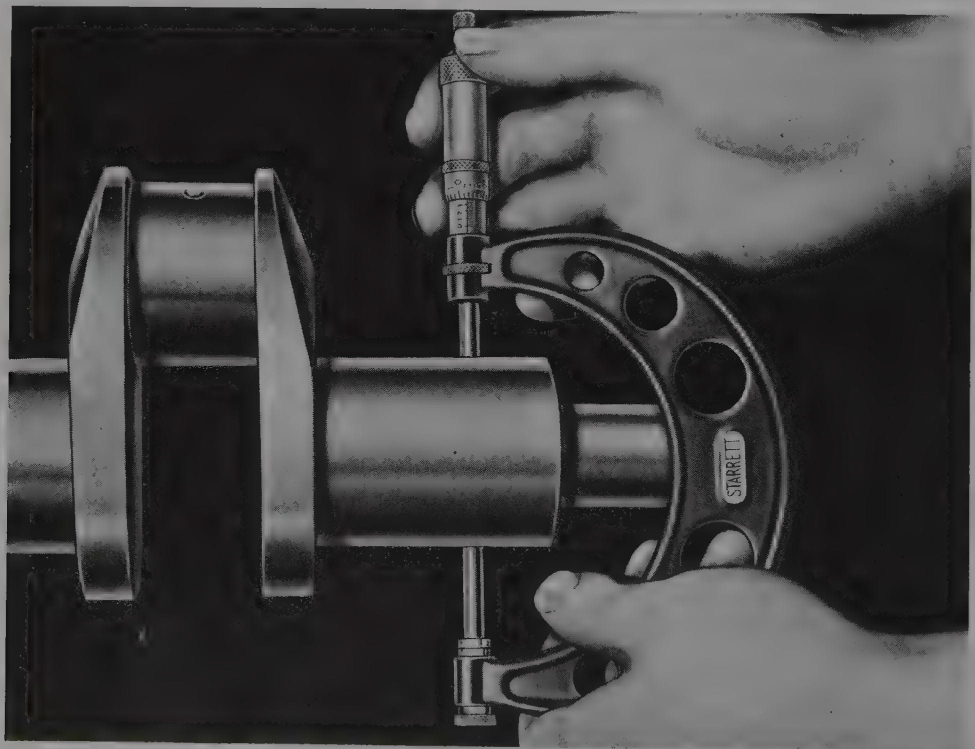


Fig. 2-13. Miking a crankshaft. Notice how mike is held.

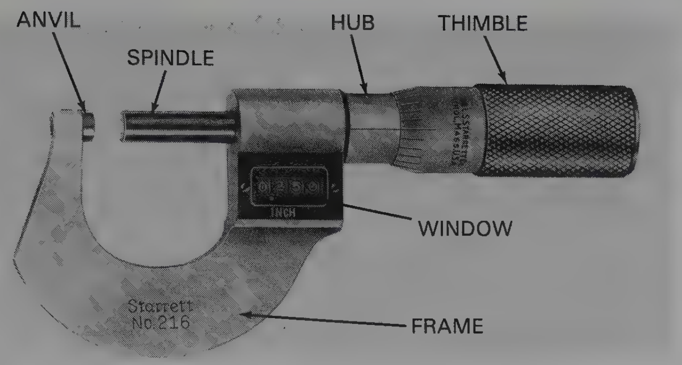


Fig. 2-15. On this digital micrometer, four numbers are shown in the window. It can be used to take readings that are accurate to one one-thousandth (.001) of an inch. (L.S. Starrett)

INSIDE MICROMETER

The inside micrometer is used for making measurements in cylinder bores, brake drums, large bushings, and similar parts, Fig. 2-16.

An inside mike is read in the same manner as the outside micrometer. The same feel is required. When measuring, rock the inside mike from side to side. At the same time, keep the anvil firmly against one side of the bore. While the free end is being rocked, it must also be tipped in and out. The rocking allows you to locate the widest part of the bore. The tipping assures that the micrometer is at right angles to the bore, Fig. 2-17.

An extension handle permits the use of an inside micrometer in a bore too small to hand hold the tool.

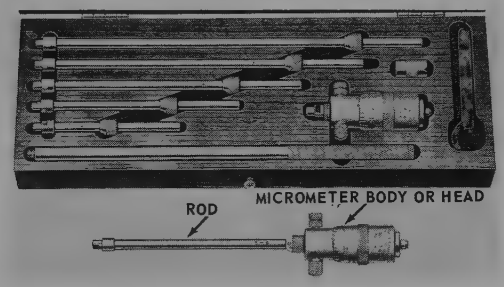


Fig. 2-16. Inside micrometer. By changing rods, this set will measure from 2 to 8 in. (L.S. Starrett)

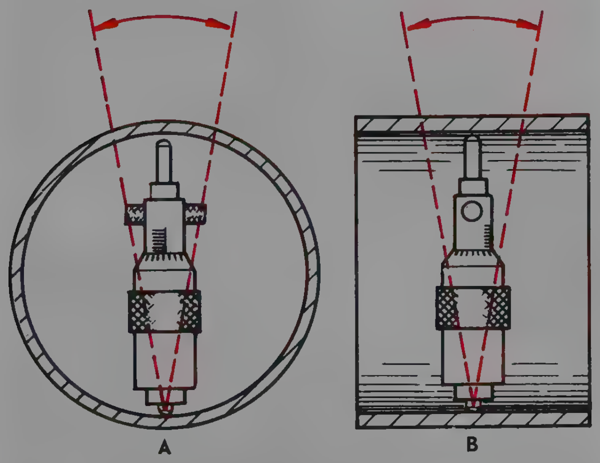


Fig. 2-17. A—Inside micrometer must be rocked from side to side. B—At the same time, it must be tipped. Both movements are relatively slight.

MICROMETER DEPTH GAUGE

This is a handy tool for reading the depth of slots, splines, counterbores, and holes.

To use this tool, the base is pressed against the work (after cleaning) and the spindle is run down into the hole to be measured.

It is read like an outside micrometer. The only difference is the sleeve marks run in a reverse direction, Fig. 2-18.

DIAL GAUGE OR INDICATOR

The dial indicator is a precision tool designed to measure movements in thousandths of an inch. Some common uses are checking end play in shafts, backlash between gears, valve lift, shaft run-out, and taper in cylinders.

Use care in the handling of this tool as it is sensitive and easily damaged. When not in use, keep it in a protective case.

Dial indicator faces are calibrated either in thousandths

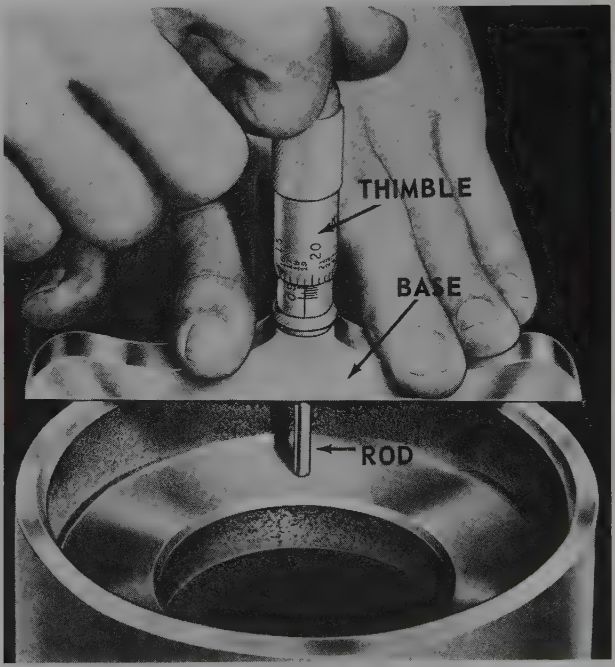


Fig. 2-18. Using the micrometer depth gauge. The base is held firmly against work and thimble turned until rod contacts shoulder.

of an inch or in millimetres. Various type dial markings are available. Ranges (distance over which indicator can be used) vary, depending upon the instrument, Fig. 2-19.

Various mounting arms, swivels, and adapters are provided so that the indicator can be used on various setups.

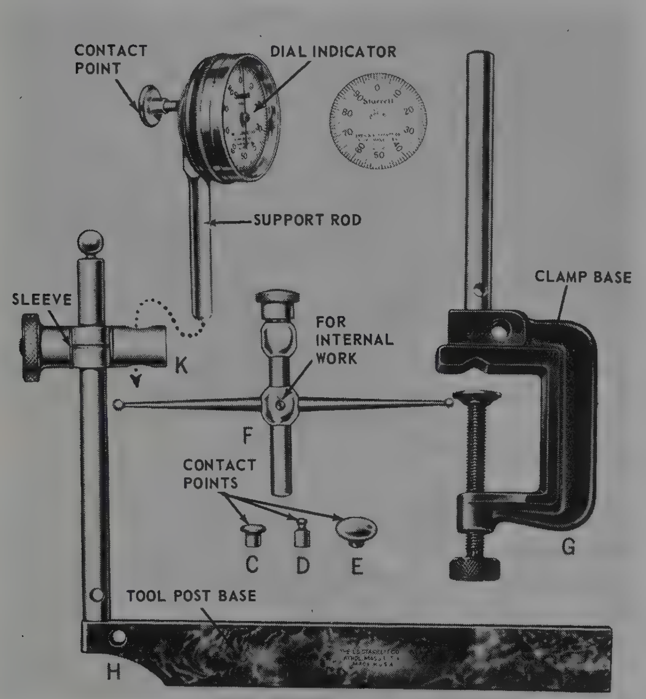


Fig. 2-19. Dial indicator and holding attachments. (L. S. Starrett)

When using a dial indicator, be certain that it is firmly mounted and that the standard (actuating rod) is parallel to the plane (direction) of movement to be measured, Fig. 2-20.

Place the rod end against the work to be measured. Force the indicator toward the work. Make the indicator needle travel far enough around the dial so that movement in either direction can be read. The dial face can then be turned to line the 0 mark with the indicator needle. Be sure that the indicator range (limit of travel) will cover the movement anticipated. Ranges usually run from around .200 to 1.000 (one inch), depending on the instrument.

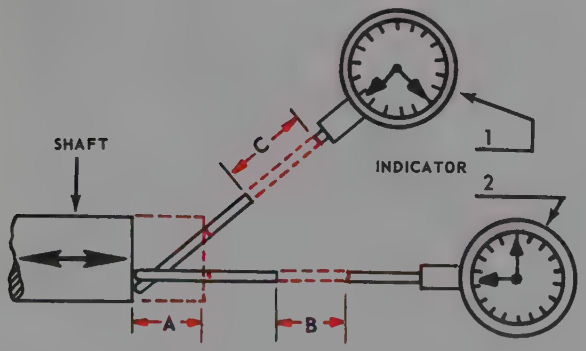


Fig. 2-20. Indicator 1 set up is NOT parallel to movement of shaft. When shaft moves distance A, indicator rod moves distance C, giving a false reading for shaft end play. Indicator 2 is parallel and shaft movement A causes indicator rod to move distance B, producing an accurate reading.

Figs. 2-21, 2-22, and 2-23 illustrate typical dial indicator setups.

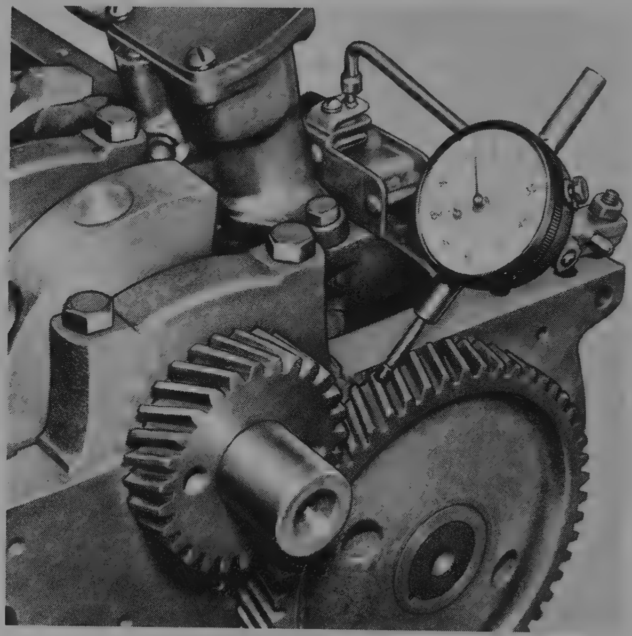


Fig. 2-21. Checking timing gear backlash with a dial indicator. Indicator rod is angled to place it in line with gear rotation. (Chevrolet)

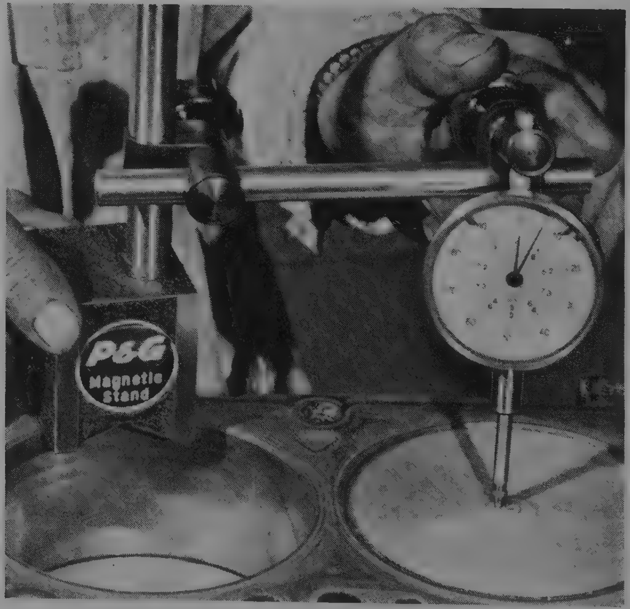


Fig. 2-22. Using a dial indicator to determine piston top dead center. (P & G Mfg. Co.)

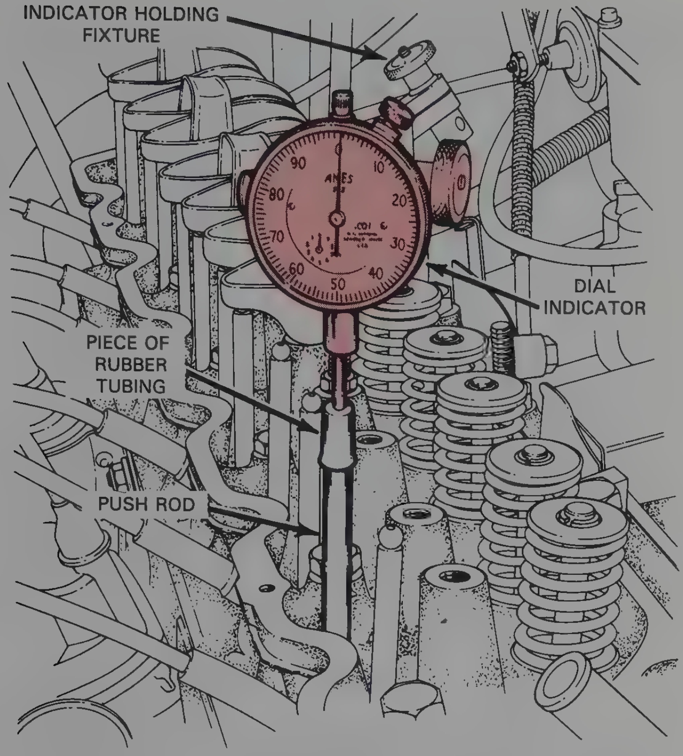


Fig. 2-23. Using a dial indicator to measure camshaft lobe lift. (Jeep)

OTHER DIAL INDICATOR TOOLS

Two other valuable measuring tools utilize a dial indicator as part of their construction. They are the out-of-roundness gauge and the cylinder gauge. The out-of-roundness gauge is used to check connecting rod big end bores. This can be done with an inside mike but this special gauge makes the job easier and faster, Fig. 2-24.

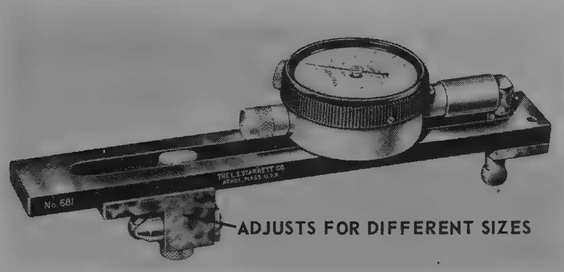


Fig. 2-24. Out-of-roundness gauge.

The cylinder gauge makes the checking of cylinder bore size, taper, and out-of-roundness quick and accurate, Fig. 2-25.

OTHER USEFUL MEASURING TOOLS

In addition to the precision tools already discussed, there are a number of other tools that a mechanic should own. Keep in mind that, in your work as an auto mechanic, a number of measurements, varying from a few thousandths to several feet, will be required.

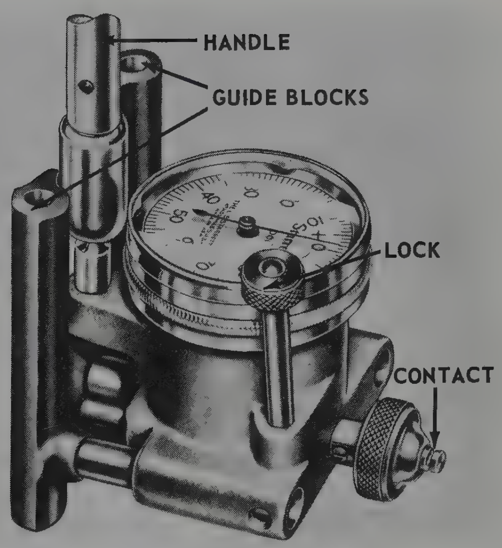


Fig. 2-25. Cylinder gauge. Only a short section of handle is shown. (L. S. Starrett)

INSIDE AND OUTSIDE CALIPERS

Calipers are useful tools for quick measurements when accuracy is not critical. Fig. 2-26 illustrates a pair of outside calipers.

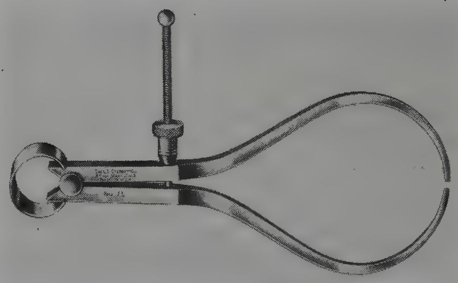


Fig. 2-26. Outside caliper.

Fig. 2-27 shows inside caliper. The inside caliper is used to measure the diameter of holes. To determine the reading, hold the calipers on an accurate steel rule. Careful measuring across the points (very light touch) with an outside micrometer will give a more accurate reading.

DIAL CALIPERS

The dial caliper is a very useful precision measuring instrument capable of obtaining inside, outside, and depth readings. Because these calipers are highly accurate,

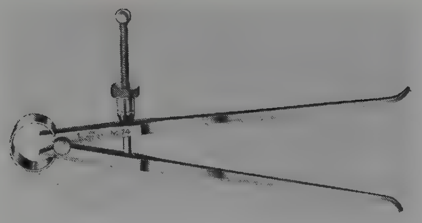


Fig. 2-27. Inside caliper.

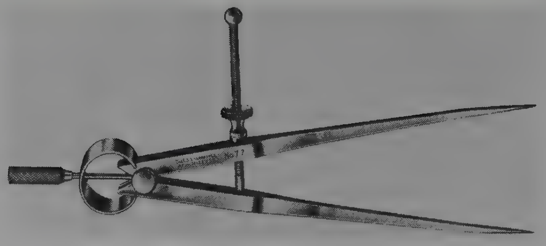


Fig. 2-29. Dividers. Points must be sharp.

they should be handled and used with great care. Always store them in a protective case when not in use.

The dial caliper shown in Fig. 2-28 will measure objects up to 6 in. (152.4 mm). The graduation lines on the bar scale (body) are each equal to .100 in. (2.54 mm). The dial is calibrated in .001 in. (0.025 mm). Every full revolution of the dial needle equals .100 inch on the bar scale.

This particular caliper is equipped with a thumb operated roll knob which aids in obtaining fine adjustments. Once the measurement is taken, the lockscrew can be tightened. This prevents the caliper from opening or closing and altering the reading, Fig. 2-28.

DIVIDERS

Dividers are somewhat like calipers but have straight shanks and pointed ends. They are handy for making circles and taking surface measurements. Fig. 2-29 illustrates a pair of dividers.

FEELER GAUGES

Feeler or thickness gauges are thin strips of specially hardened and ground steel, with the thickness marked in thousandths of an inch and/or millimetres. They are used to check clearances between two parts (valve gap, piston ring side and end gap clearance for example). They come in sets as shown in Fig. 2-30, in 12 in. or longer lengths, and in nonferrous versions.

WIRE GAUGE

The wire gauge is a thickness gauge using wires of varying diameter instead of thin flat strips of steel. It is excellent for checking spark plug gaps and distributor point gap. See Fig. 2-31.

SCREW PITCH GAUGE

This is a handy tool for determining the number of threads per inch on bolts, screws, and studs, Fig. 2-32.

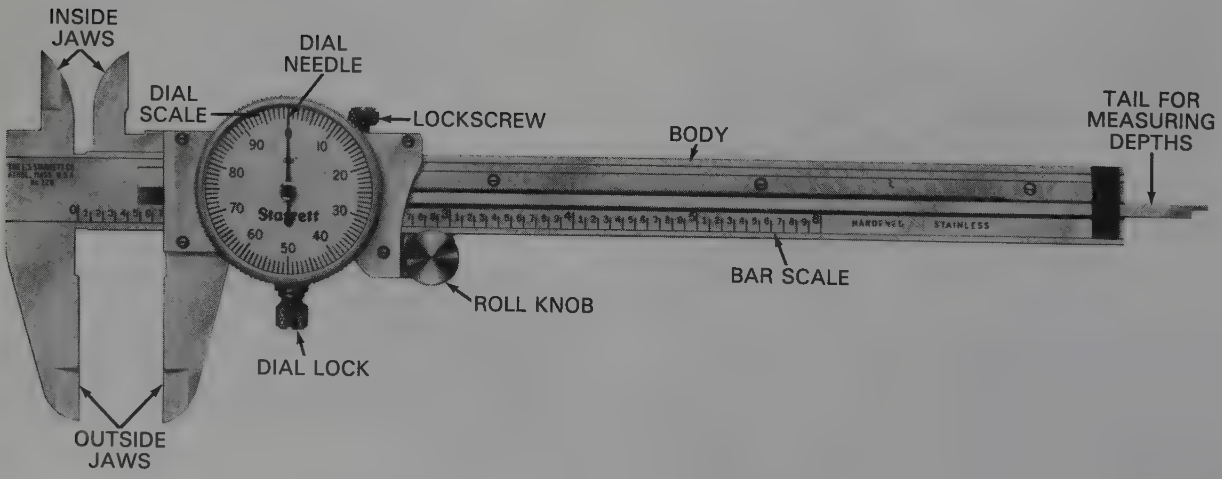


Fig. 2-28. Dial caliper. This instrument will measure objects, holes, etc., up to 6 inches (152.4 mm) in diameter and depth. (L.S. Starrett)

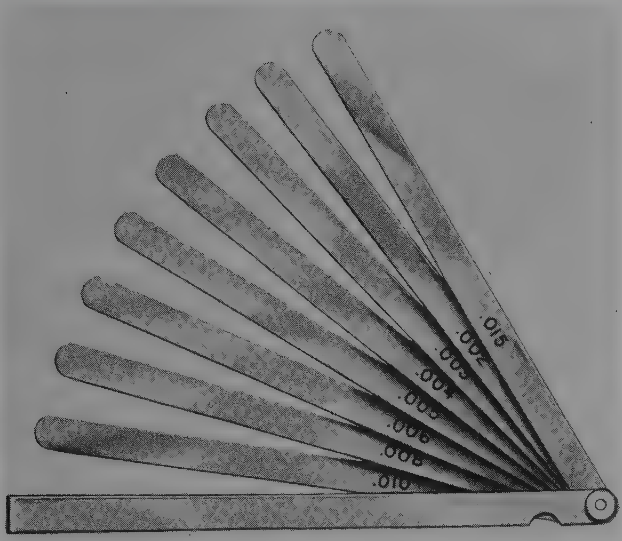


Fig. 2-30. Feeler gauge set. (Owattona Tools)

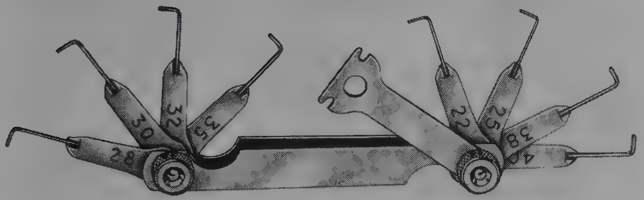


Fig. 2-31. Wire gauge set for checking spark plug gap.

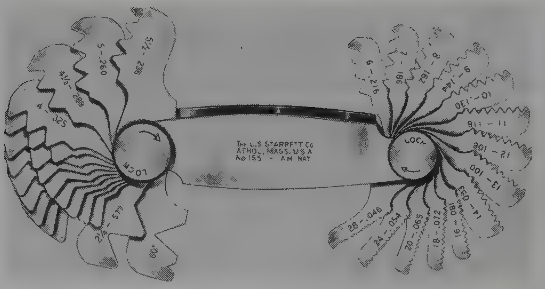


Fig. 2-32. Screw pitch gauge. First or small number indicates number of threads per inch. Second number indicates double depth of the threads.

TELESCOPING GAUGE

The telescoping gauge is an accurate tool for measuring inside bores of engine connecting rods and main bearings. To use this tool, the plungers are compressed and locked by turning the knurled screw on the handle. The gauge is placed inside the bore. The plungers are then released until they contact the bore walls. Next, they are locked and the tool is removed. An outside micrometer is used to measure across the plungers for an accurate checking of bore size. Telescoping gauges have different ranges and may be purchased in sets. The proper feel for using this tool will be the same as the inside micrometer, Fig. 2-33.

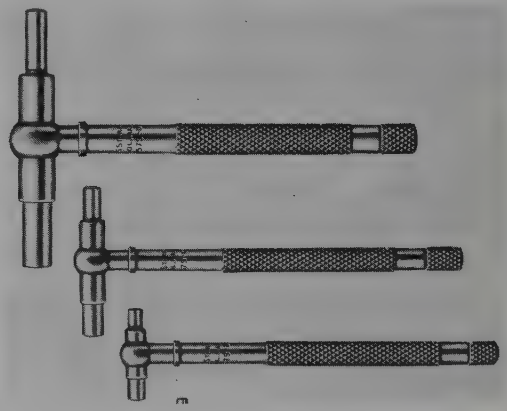


Fig. 2-33. Telescoping gauges. Gauges shown will cover a range from 1/2 to 2 1/2 in. (12.70 to 63.50 mm). (L. S. Starrett)

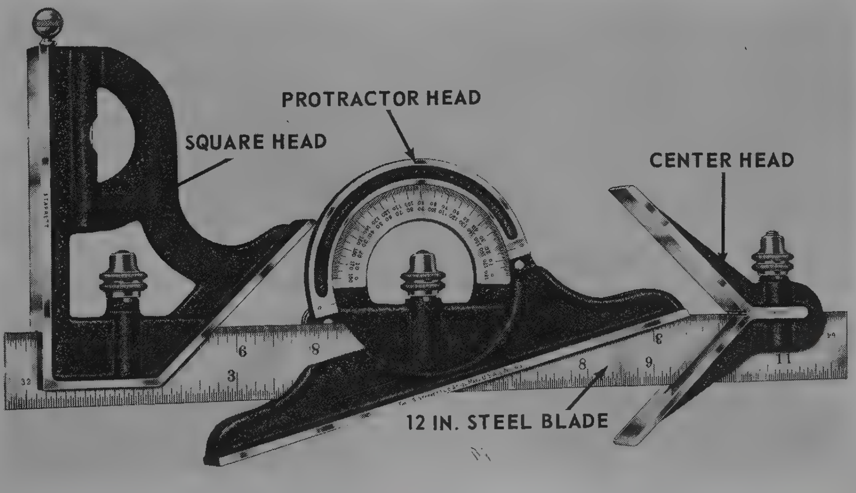


Fig. 2-34. Combination square with center head and protractor. (L. S. Starrett)

STEEL RULES

Other measuring tools that can be used to good advantage include:

1. A thin, six inch steel hook rule with a sliding steel head, marked in 32nds and 64ths.
2. A combination square made up of a steel rule, protractor head, center head, and square.
3. A ten foot pocket tape rule.

See Figs. 2-34 and 2-35.

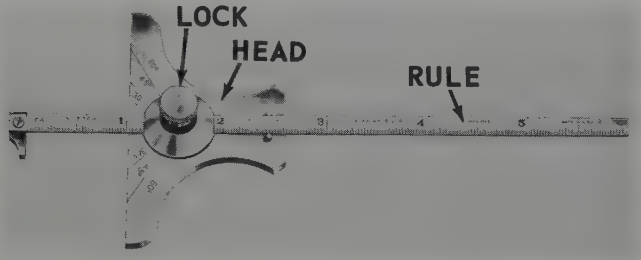


Fig. 2-35. 6 in. hook rule with sliding depth and angle head.

SPRING SCALE

Two spring scales, one reading in ounces and the other in pounds, are a "must." These are needed to determine contact point pressure and pull on feeler strips when fitting pistons. Look at Fig. 2-36.

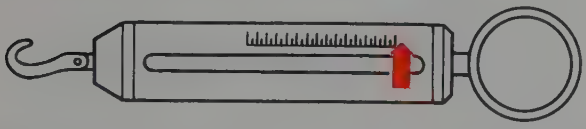


Fig. 2-36. Spring scale. A must in every tool kit.

STEEL STRAIGHTEDGE

An accurate steel straightedge is used to check part warpage. It should be long enough to span the length of an engine block or head for checking these parts for warpage. Be careful when handling and storing a straightedge. It must not be damaged, Fig. 2-37.

TEMPERATURE IS IMPORTANT

Many specifications for measurements will state room temperature, an exact temperature, or engine at normal running temperature. Remember that all metals contract and expand in direct proportion to their temperature. This makes it imperative that temperature specifications be followed when making precision measurements and settings. Your measuring tools themselves can be affected by extremes of heat and cold. If your tools must be used when very cold or very hot, check them for accuracy before using.

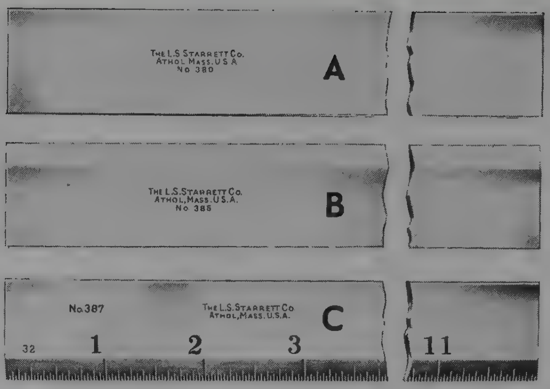


Fig. 2-37. Steel straightedge. A—Square edge. B—Bevel edge. C—Bevel and ruled edge. These are available in different lengths.

SUMMARY

It is important for you to select and correctly use the measuring tools. This will help you take highly accurate measurements, and is a MUST for all auto mechanics.

Precision tools require cleanliness, careful handling, and proper storage.

The mechanic should own, or have available, outside and inside micrometers, micrometer depth gauge, dial indicator setup, inside and outside calipers, dial calipers, dividers, feeler gauges, wire gauge, screw pitch gauge, telescoping gauge, steel rules, a straightedge, and spring scales.

Other specialized measuring tools may be acquired as the need dictates.

SUGGESTED PRACTICE JOBS

A. Practice reading both a standard and metric micrometer until you can make a correct reading every time.
B. Use an outside micrometer to measure several objects of known size.
C. Measure the inside diameter of a cylinder of a known size with your inside micrometer.
D. Using a depth gauge, measure the distance from the surface of a cylinder head to the top of a valve guide. (Valve-in-head engine.)
E. Check the runout on a camshaft by using a dial indicator.
F. Measure the inside diameter of a wrist pin bore using a telescoping gauge and an outside micrometer.
G. Check the accuracy of an outside micrometer by using a STANDARD (measuring rod of exact length) furnished for this purpose.
H. Check the accuracy of an inside mike by using the

outside micrometer you have just checked with the standard.

I. Check the gap between spark plug electrodes by using a wire gauge.

J. Determine the number of threads per inch on a bolt by using a screw pitch gauge.

K. Using a spring scale, determine the amount of tension required to move a feeler strip while fitting a piston to its cylinder bore.

L. With a straightedge, check the surface of a cylinder block for warpage.

SUGGESTED ACTIVITIES

1. Place a wrist pin in the freezer compartment of a refrigerator. When thoroughly cold, remove, wipe, and quickly measure both the diameter and length using an outside micrometer. (Hold the wrist pin with a cloth.) Write down your readings.

   Now place the wrist pin in boiling water. When hot, remove, dry, and quickly recheck diameter and length. Was there a difference? If so, how much? What does this indicate?
2. Explain how to read a micrometer to a friend that does not know how. Have your friend try a reading and continue to help until your friend does it correctly. By doing this, you will reinforce your own knowledge.

KNOW THESE TERMS

Micrometer, Depth gauge, Small hole gauge, Dial indicator, Magnetic stand, Out-of-roundness gauge, Cylinder gauge, Caliper, Dividers, Feeler gauge, Telescoping gauge, Spring scale, Steel straightedge.

QUIZ - Chapter 2

1. When using a micrometer, make sure that the tool is clamped around the work tightly. True or False?
2. Measuring tools are rustproof. True or False?
3. A micrometer should be checked accuracy __________ if accidentally dropped.
4. An inside micrometer is read in the same fashion as the outside micrometer. True or False?
5. To measure an object 3.500 in. (88.90 mm) in diameter, you would use a micrometer with a range of 3 to 4.
6. Select the correct (some are wrong) readings for the following 0-1 in. micrometer settings.

__________a.

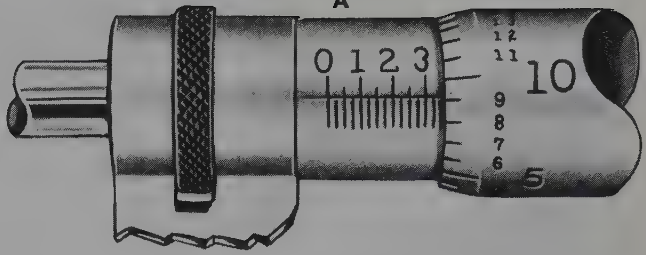
__________b.

__________c.

__________d.

__________e.

A



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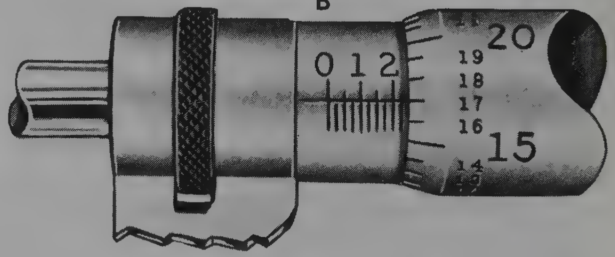
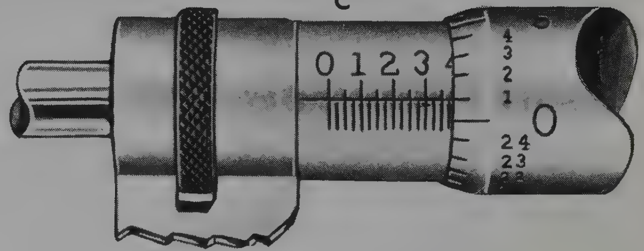
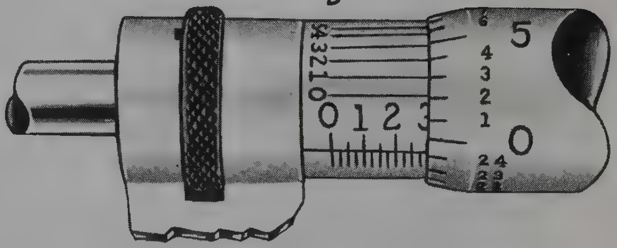


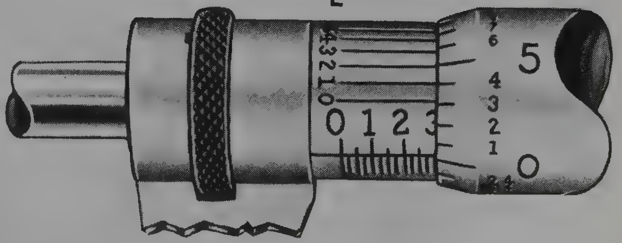
C



D



E



.359 a	.349	.3001 e	.3003	.2994
.376 c	.286	.243	.242	.2991 d

7. Name the best tool to handle each one of the following measurements:
   - a. Diameter of a wrist pin.
   - b. Diameter of a cylinder bore.
   - c. Distance from face of cylinder head to valve guide top.
   - d. End play in crankshaft.

e. Diameter of wrist pin bore in a piston.
f. Connecting rod big end bore diameter.
g. Lash (free movement or play) between two gears.
h. Teeth per inch on a bolt.
i. Clearance between the valve stem and rocker. (Valve-in-head engine.)
j. Diameter of an exhaust pipe.
k. Spark plug gap.
l. Disc brake rotor runout.
m. Length of a muffler.
n. Distance between the fan blades and radiator.
o. Engine block surface for warpage.

8. Select the correct decimal readings for the following (a-i). (Some are incorrect.)

______a. Two inches, three-hundred and twenty-five thousandths.
______b. Eight-hundred and seventy-eight and one-half thousandths.
______c. Four inches, six-hundred and thirteen and one-quarter thousandths.
______d. Three and one-half inches.
______e. One ten-thousandth of an inch.
______f. One thousandth of an inch.
______g. One hundredth of an inch.
______h. One tenth of an inch.
______i. One inch.

2.325
4.61325
.8785
.0001
.010
.100
3.500

1.000
.001
4.613025
.1000
2.30025
3.005
.01010

WHAT IS YOUR OPINION?

A person has just applied for a job as a mechanic. The garage has a reputation for excellent work. The owner is interested; there is an opening; the pay is good. So the owner introduces the applicant to you, who, as shop supervisor, will be expected to evaluate this person's worth as a mechanic.

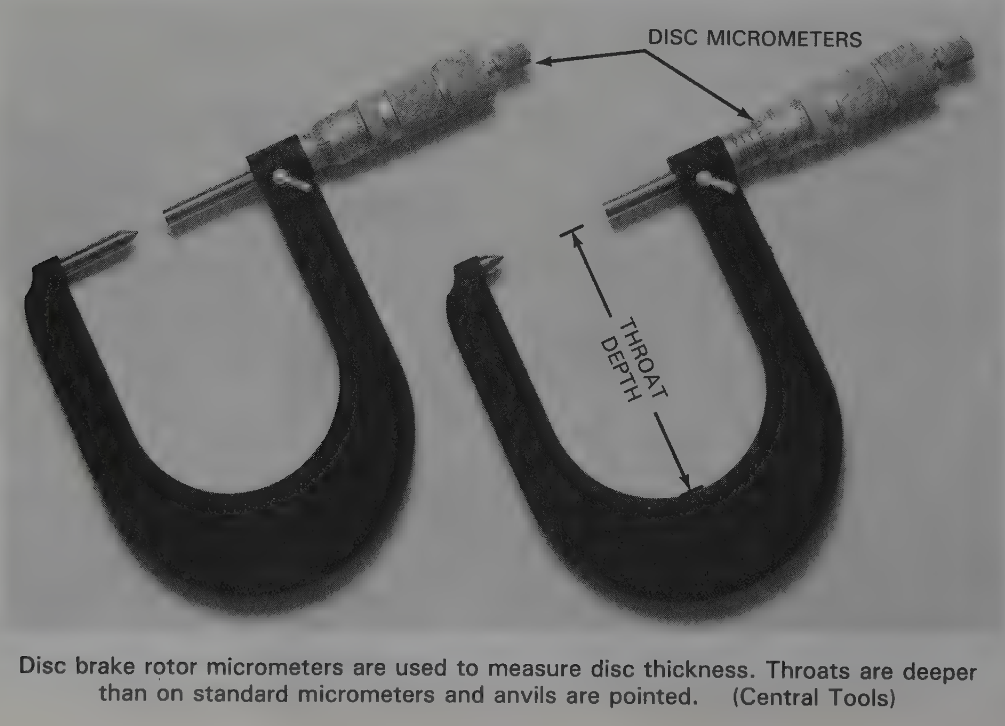
You walk to a nearby service bench, open your tool chest and lay out a selection of measuring tools. You indicate a specific cylinder bore you would like miked, and inform the applicant to choose the tools and make the measurement.

The applicant picks up an inside caliper and a six inch steel rule, adjusts the caliper in the bore, then places the caliper on the face of the six inch rule. After some squinting, the applicant informs you that the bore diameter is "just a whisker over four inches."

The actual bore diameter is 4.030. What do you think of the applicant's ability? Will you recommend hiring this person? If not, why?

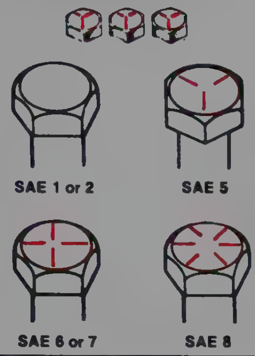
REMEMBER:

No one can be termed a top-notch mechanic who is not familiar with and competent in the use of measuring tools. You can be proud of your ability to make precision measurements—it is the mark of a fine mechanic!

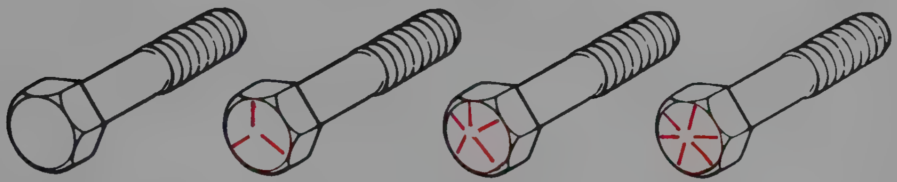


Disc brake rotor micrometers are used to measure disc thickness. Throats are deeper than on standard micrometers and anvils are pointed. (Central Tools)

Standard Torque Specifications and Capscrew Markings Chart

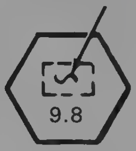
CAPSCREW HEAD MARKINGS	CAPSCREW BODY SIZE Inches — Thread	SAE GRADE 1 or 2 (Used Infrequently)		SAE GRADE 5 (Used Frequently)		SAE GRADE 6 or 7 (Used at Times)		SAE GRADE 8 (Used Frequently)	
		Torque		Torque		Torque		Torque	
		Ft-Lb	Nm	Ft-Lb	Nm	Ft-Lb	Nm	Ft-Lb	Nm
Manufacturer's marks may vary. Three-line markings on heads shown below, for example, indicate SAE Grade 5. 	1/4-20	5	6.7791	8	10.8465	10	13.5582	12	16.2698
	-28	6	8.1349	10	13.5582			14	18.9815
	5/16-18	11	14.9140	17	23.0489	19	25.7605	24	32.5396
	-24	13	17.6256	19	25.7605			27	36 6071
	3/8-16	18	24.4047	31	42.0304	34	46.0978	44	59.6560
	-24	20	27.1164	35	47.4536			49	66.4351
	7/16-14	28	37.9629	49	66.4351	55	74.5700	70	94.9073
	-20	30	40.6745	55	74.5700			78	105.7538
	1/2-13	39	52.8769	75	101.6863	85	115.2445	105	142.3609
	-20	41	55.5885	85	115.2445			120	162.6960
	9/16-12	51	69.1467	110	149.1380	120	162.6960	155	210.1490
	-18	55	74.5700	120	162.6960			170	230.4860
	5/8-11	83	112.5329	150	203.3700	167	226.4186	210	284.7180
	-18	95	128.8027	170	230.4860			240	325.3920
	3/4-10	105	142.3609	270	366.0660	280	379.6240	375	508.4250
	-16	115	155.9170	295	399.9610			420	569.4360
	7/8- 9	160	216.9280	395	535.5410	440	596.5520	605	820.2590
	-14	175	237.2650	435	589.7730			675	915.1650
	1- 8	235	318.6130	590	799.9220	660	894.8280	910	1233.7780
	-14	250	338.9500	660	894.8280			990	1342.2420

A



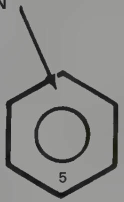
GRADE 2 (GM 260-M) GRADE 5 (GM 280-M) GRADE 7 (GM 290-M) GRADE 8 (GM 300-M)

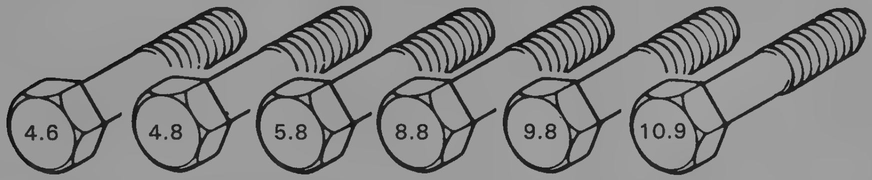
MANUFACTURER'S IDENTIFICATION



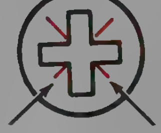
B CUSTOMARY (INCH) BOLTS-IDENTIFICATION MARKS CORRESPOND TO BOLT STRENGTH-INCREASING NUMBERS REPRESENT INCREASING STRENGTH.

NUT STRENGTH IDENTIFICATION





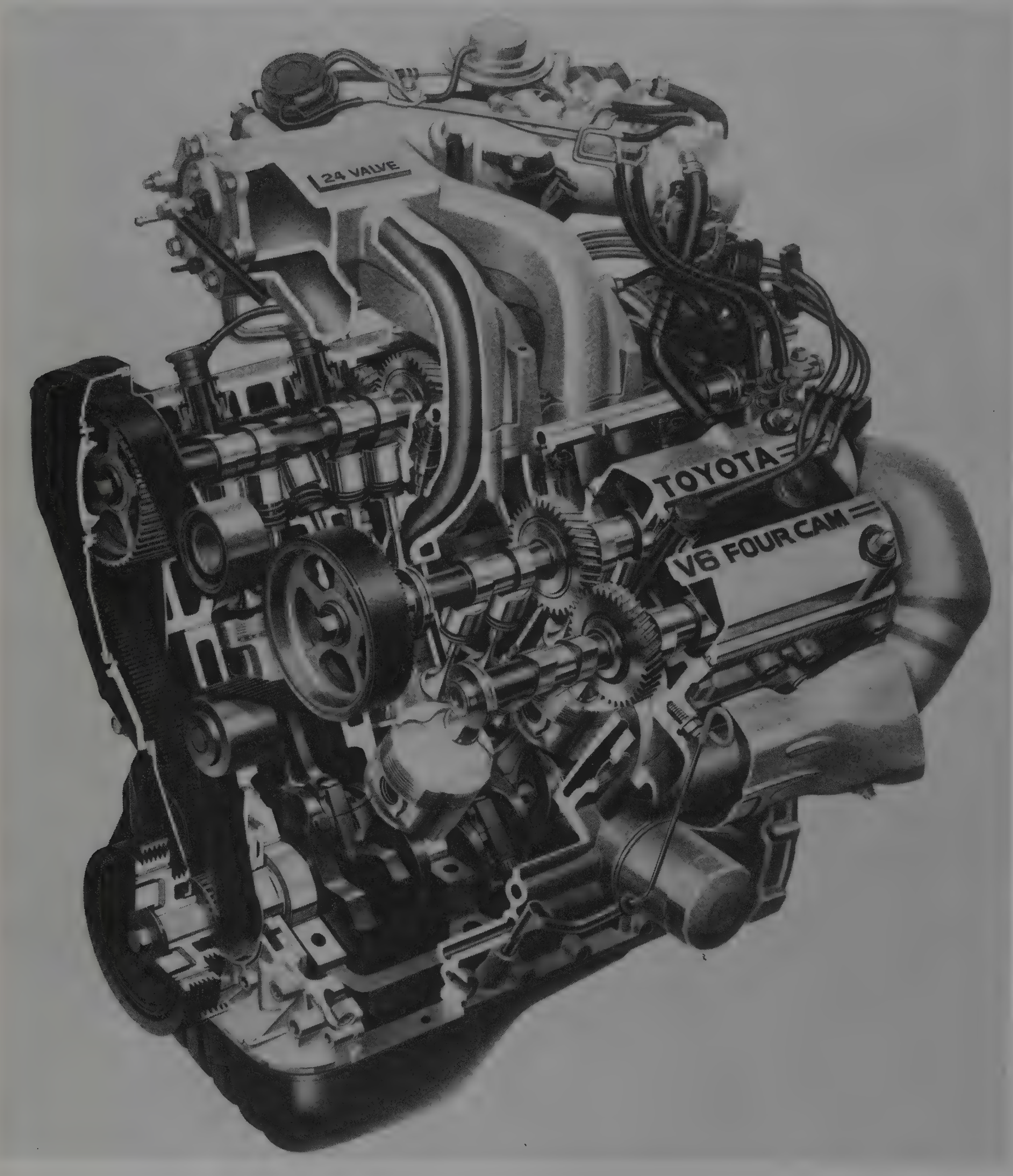
POSIDRIV SCREW HEAD



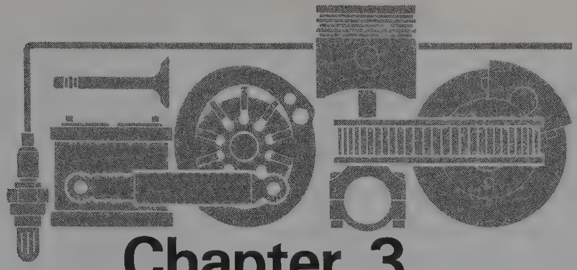
IDENTIFICATION MARKS (4)

C METRIC BOLTS-IDENTIFICATION CLASS NUMBERS CORRESPOND TO BOLT STRENGTH-INCREASING NUMBERS REPRESENT INCREASING STRENGTH.

Chart shows typical torque for cap screws with threads clean and dry. Reduce torque by 10 percent if threads are oiled; reduce by 20 percent if new, plated fasteners are used for various fastener grades. ALWAYS FOLLOW MANUFACTURER'S TORQUE SPECIFICATIONS FOR THE EXACT JOB AT HAND. A—Cap screws, bolts, and nuts are marked with either lines or numbers to indicate their relative strength. B—Customary (inch) bolt markings. Note that strength (grade) corresponds to number of lines. There are always two lines less then actual grade. C—Metric bolt markings. Higher grade (customary) or number (metric), the greater the strength. (American Motors, General Motors)


24 VALVE
TOYOTA
TOYOTA
V6 FOUR CAM

Cutaway view of an electronic, fuel injected, 2.5-liter, V-6 engine that uses four camshafts and 24 valves. (Toyota)



Chapter 3

FASTENERS, TORQUE WRENCHES

After studying this chapter, you will be able to:

- ☐ Identify automotive fasteners.
- ☐ Properly select fasteners.
- ☐ Torque fasteners to specifications when needed.
- ☐ Repair damaged or broken fasteners.

INCREASING IMPORTANCE

In the modern car, various components are subjected to heavy loads, high frequency vibration, heat, and severe stress. As a result, fastener (nuts, bolts, screws) design, material, and torque settings have assumed a position of major importance.

It is important that the mechanic become familiar with the various types, uses, and proper installation of fasteners.

READ CAREFULLY

Be sure to read this chapter carefully. Study the various fasteners, their markings, and uses until you can recognize them immediately. Pay particular attention to the section on torque wrenches.

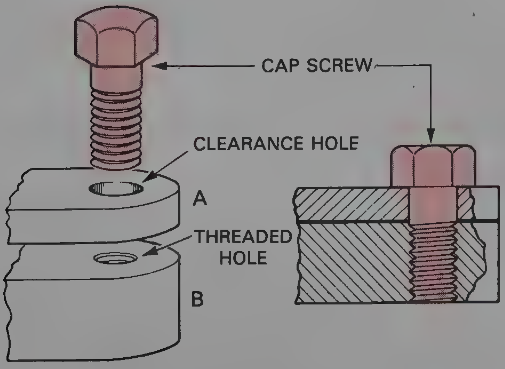


Fig. 3-1. Cap screw. Cap screw is passed through clearance hole in part A and threaded into part B.

MACHINE SCREWS

Machine screws are used without nuts. They are passed through one part and threaded into another. When drawn up, the two parts are then held in firm contact. Fig. 3-1 illustrates the use of a cap screw (machine screw with a hexagonal head).

There are many different types of machine screws and screw heads. Fig. 3-2 shows a number of those in common use.

SELF-TAPPING OR SHEET METAL SCREWS

Sheet metal screws are used to fasten thin metal parts together and for attaching various items to sheet metal.

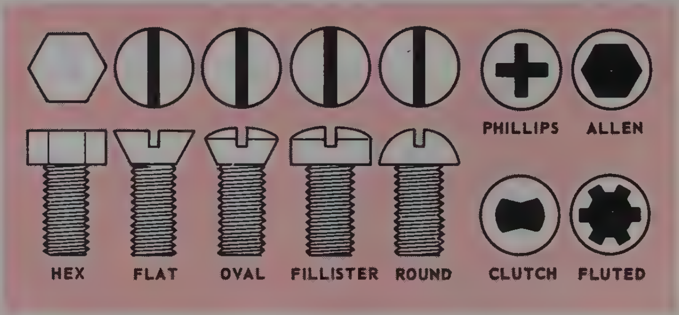


Fig. 3-2. Typical machine screws. Four heads at right illustrate various openings for turning tools.

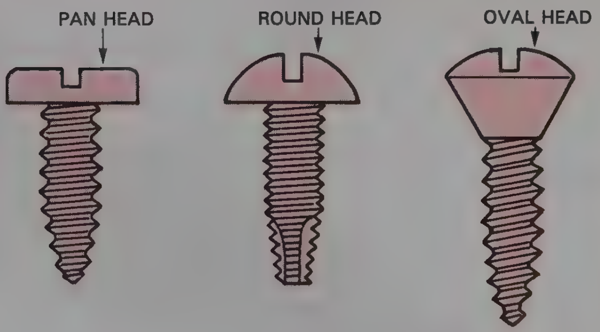


Fig. 3-3. Typical sheet metal screws.

They are much faster and less expensive than bolts, Fig. 3-3.

To use a sheet metal screw, punch a hole in the sheet metal. The hole should be slightly smaller than the screw minor diameter (diameter of screw if threads were ground off). A punched hole is better than a drilled hole because the punched hole attempts to close as the screw is tightened. This provides added gripping power, Fig. 3-4.

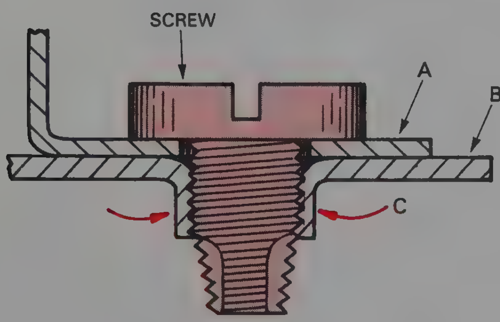


Fig. 3-4. Screw passes freely through A and cuts threads in punched hole in B. When screw tightens, punched metal draws up and in, providing a secure grip, C.

BOLT

A bolt is a metal rod that has a head at one end and a screw thread for a nut at the other. The bolt is passed through the parts to be joined. Then, the nut is installed and drawn up. This holds the parts together, Fig. 3-5.

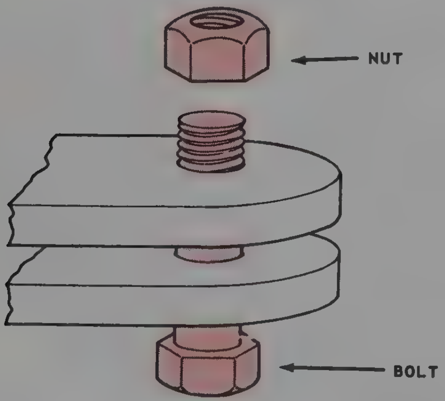


Fig. 3-5. Using a bolt to hold two parts together.

STUDS

A stud is a metal rod threaded on both ends. The stud is turned into a threaded hole in a part. The other part is slipped over the stud. A nut is turned down on the stud to secure the part. Studs are available in many lengths and diameters. Some have a coarse thread on one end and a fine thread on the other. Others have the same thread on both ends. In some cases, this thread may run the full length of the stud, Fig. 3-6.

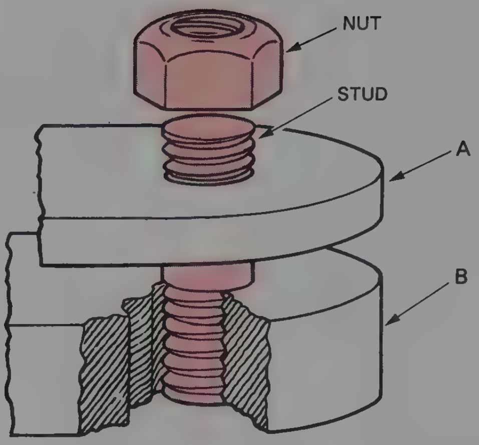


Fig. 3-6. Stud threaded into B. Part A slipped over stud. Nut is placed on stud and tightened.

A stud wrench should be used to install or remove studs. Be careful not to damage the threads. If no stud wrench is available, place two nuts on the stud and "jam" them together (turn the top one clockwise, the bottom counterclockwise until they come together). Place a wrench on the lower nut to remove the stud and on the upper nut to install. See Fig. 3-7.

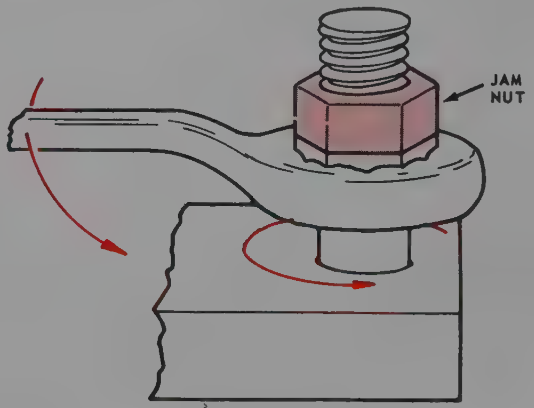


Fig. 3-7. Using jam nuts and wrench to remove stud.

REMOVING BROKEN STUDS OR SCREWS

There are several methods for removing broken fasteners. If a portion of the fastener projects above the work, it may be gripped with vise-grip pliers, or a small pipe wrench and backed out.

Where the portion protruding is not sufficient to grasp with pliers or a wrench, flat surfaces may be filed to take a wrench. Also, a slot may be cut to allow the use of a screwdriver, Fig. 3-8, A.

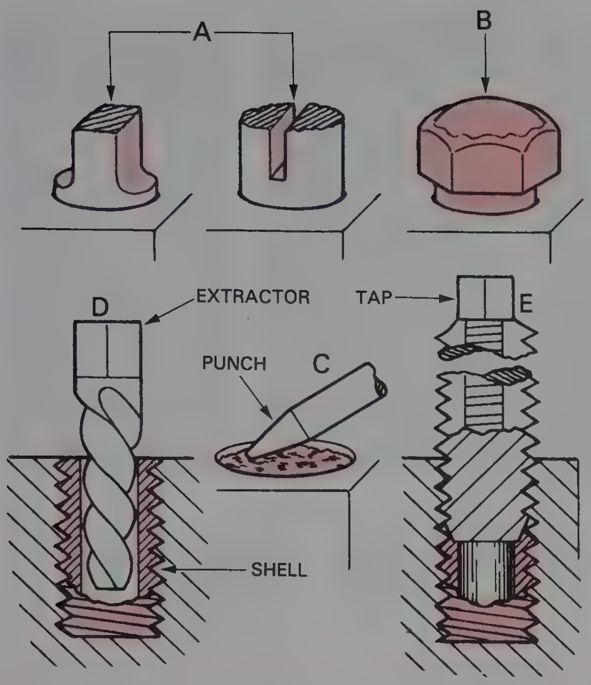


Fig. 3-8. Methods used in removing broken stud. A—Stud slotted or filed flat. B—Nut welded on. C—Punch used to unscrew broken piece. D—Screw extractor. E—Using a tap to remove shell.

Another method is to drill a hole in a section of flat steel, place it over the broken stud and weld the strip to the stud. A nut large enough to fit over the stud can also be welded on. The arc welder does the job quickly and with a minimal amount of heating, Fig. 3-8, B. WHEN WELDING, BE CAREFUL OF FIRE AND DAMAGE TO PARTS.

When the stud is broken off flush or slightly below the surface, you may use a thin, sharp pointed punch. Try driving the broken section in a counterclockwise direction. Sometimes the stub will turn out easily. If you are not getting results, stop and try another method, Fig. 3-8, C.

A screw extractor can often be used with good results. Center punch in the EXACT center of the stub. Drill through the stub with a small diameter drill. Then, run a drill through that is slightly smaller than the stud minor diameter. Lightly tap the extractor into the shell that remains and back it out with a wrench. The sharp edges on the flutes will grip the shell. Do not exert enough turning force to break the extractor. It could present a real problem since it is hardened. See Fig. 3-8, D.

In the event the methods previously described fail, select the proper tap size drill and after running it through the stub shell, carefully tap out the hole. If done properly, the tap will remove the shell threads leaving the original threads in the hole undamaged, Fig. 3-8, E.

When drilling, drill through the stub only. Do not drill beyond as you may damage the part. If working on a setup where metal chips may fall into a housing, coat the drill and tap with a heavy coat of sticky grease. The chips will adhere to the grease and tools.

REMOVING DAMAGED NUTS

Occasionally, nuts will be difficult to remove due to rust, dirt, and corrosion. When this happens, there are several methods you may use to assist removal: HEAT (a fire hazard, be careful!), NUT-SPLITTER (CRACKER), or CHISEL and HACKSAW. See Fig. 3-9.

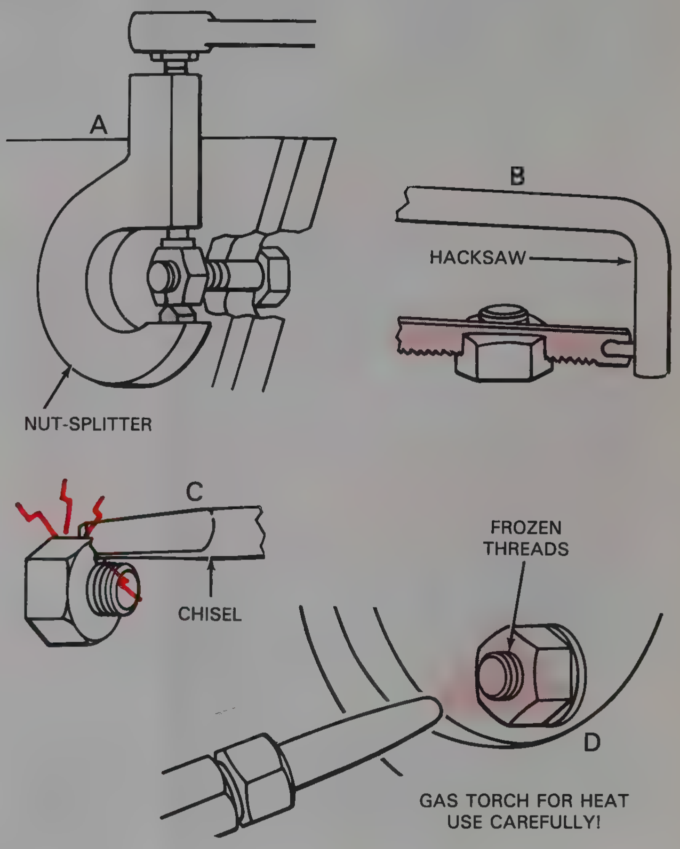


Fig. 3-9. Four common methods of removing stubborn nuts. A—Nut splitter. B—Hacksaw. C—Chisel. D—Gas torch. (Deere & Co.)

USE PENETRATING OIL

Regardless of the method of removal, it is a good idea to apply penetrating oil (special light oil used to free rusty and dirty parts) to the area and give it a few minutes to work in. If heat is not injurious to the part, an application of heat will also help. Use caution not to overheat. If in doubt as to the effects - do not apply heat. NEVER USE A TORCH NEAR A GAS TANK, BATTERY, OR OTHER FLAMMABLE MATERIALS.

REPAIRING THREADS

Occasionally threads, both external and internal, are only partially stripped. In such cases, they can be readily cleaned up through the use of a thread die or a tap. See Fig. 3-10.

When threads in holes are damaged beyond repair, one of four things can be done:

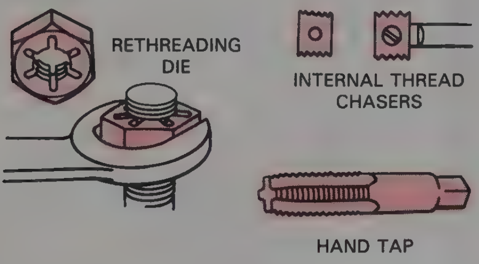


Fig. 3-10. Some thread restoring tools. (Deere & Co.)

1. The hole may be drilled and tapped to the next suitable oversize. Then, a larger diameter cap screw or stud can be installed. Use a chart to determine the proper size (tap size) to use. A clearance or body drill (drill the size of the bolts major diameter) must be passed through the attaching part to allow an oversize cap screw to be used, Fig. 3-11.

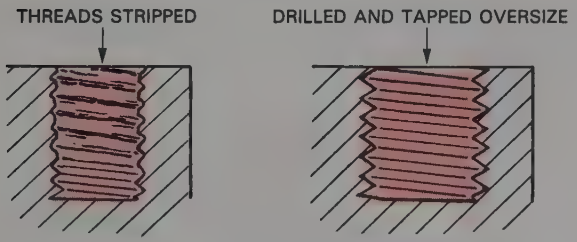


Fig. 3-11. Repairing stripped thread by drilling and tapping to next oversize.

2. The hole may be drilled and tapped to accept a threaded plug. The plug should also be drilled and tapped to the original screw size. A special self-tapping plug already threaded to the original size may be used. You merely drill a hole to the specified size. Run the threaded plug into a hole using a cap screw and jam nut. When fully seated, the jam nut is loosened and the cap screw removed, Fig. 3-12.
3. Another method makes use of a patented coil wire insert called a Heli-Coil. The hole is drilled then tapped with a special tap. A Heli-Coil is then inserted. This brings the hole back to its original diameter and thread, Fig. 3-13.
4. Another type of thread repair similar to the Heli-Coil is called Keensert. Instead of being an open coil insert, the Keensert is a hollow type plug with internal and external threads. The damaged threaded hole is drilled and tapped with a special tap. The Keensert is then installed by hand until slightly below the top of the hole.

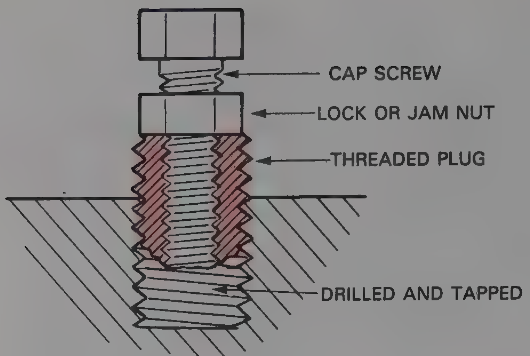


Fig. 3-12. Inserting threaded plug to repair stripped threads.

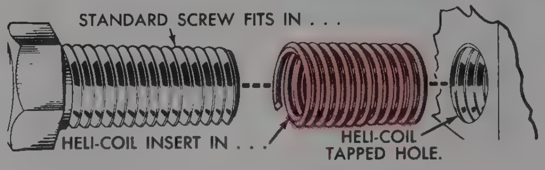


Fig. 3-13. Repairing stripped threads by using a Heli-Coil installation. (Chrysler)

A special punch is then used to force the four locking fingers down the slots cut into the insert. The top half of each finger is wider than the bottom causing it to cut into the threaded hole, locking the insert firmly into position. This brings the hole to the original diameter and thread. See Fig. 3-14.

The insert may be removed using special tools if it becomes damaged.

REMEMBER

When removing a broken screw or repairing stripped threads, proceed carefully. A frantic or careless attempt at repair can often cause serious and costly trouble.

NUTS

Nuts are manufactured in a variety of sizes and styles. Nuts for automotive use are generally hexagonal in shape (six sided). They are used on bolts, studs, and obviously must be of the correct diameter and thread pitch (threads per inch), Fig. 3-15.

BOLT AND SCREW TERMINOLOGY

Bolts and screws may be identified by type, length, major diameter, pitch (threads per inch), length of

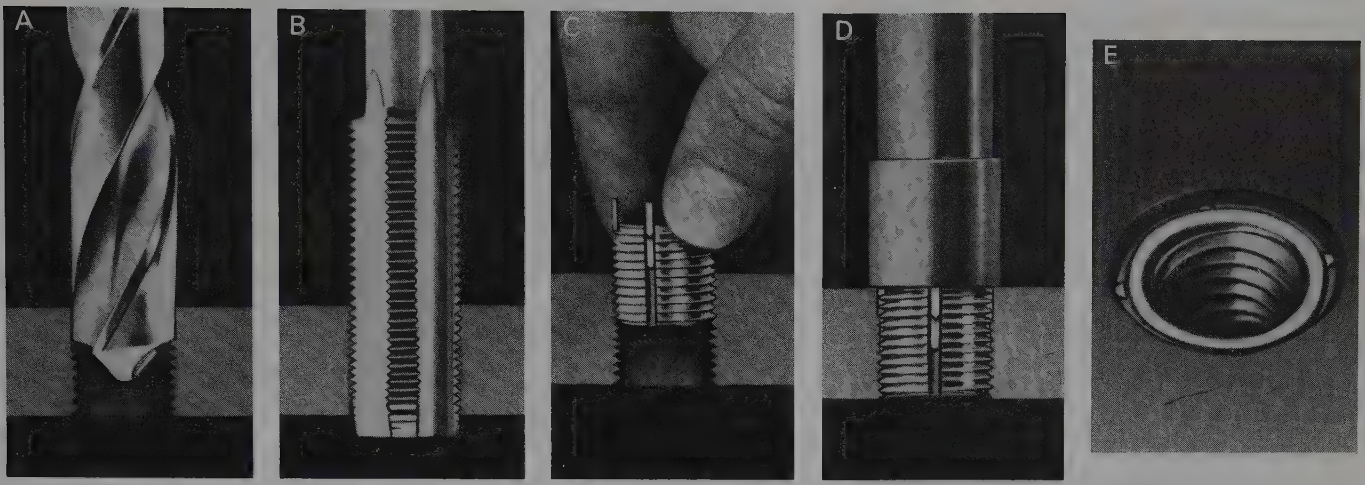


Fig. 3-14. Keensert internal thread repair sequence. A—Drill out old damaged threads. B—Cut new threads with tap. C—Insert is screwed in until it is slightly below hole surface. D—Fingers are driven into place with several light taps on the installation tool. E—Installed insert. Hole is now back to original inside diameter and ready to be used. (Rexnord)

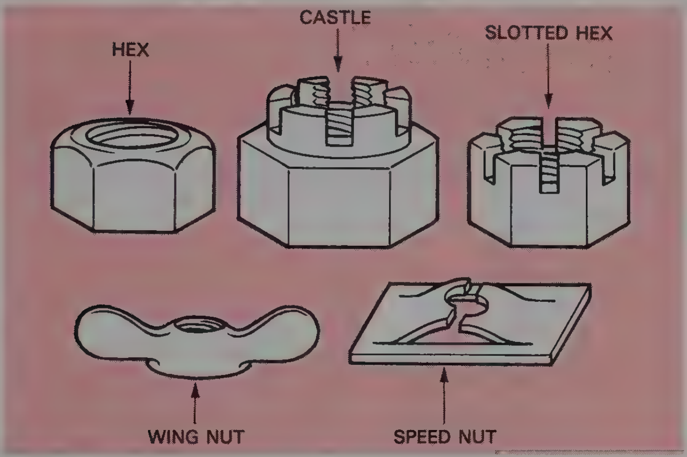

CASTLE
HEX
SLOTTED HEX
WING NUT
SPEED NUT

Fig. 3-15. Common nuts. Wing nut is installed and removed with fingers. Speed nut is used in fastening sheet metal or other parts not requiring strength of regular nut.

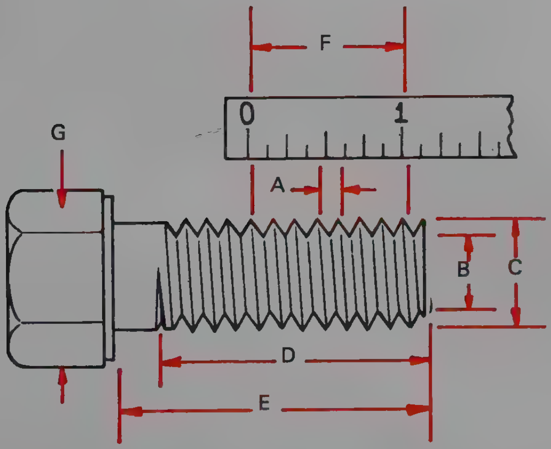


Fig. 3-16. Bolt and screw terminology. A—Pitch. B—Minor diameter. C—Major diameter. D—Thread length. E—Screw length. F—Threads per inch. G—Head size measured across flats.

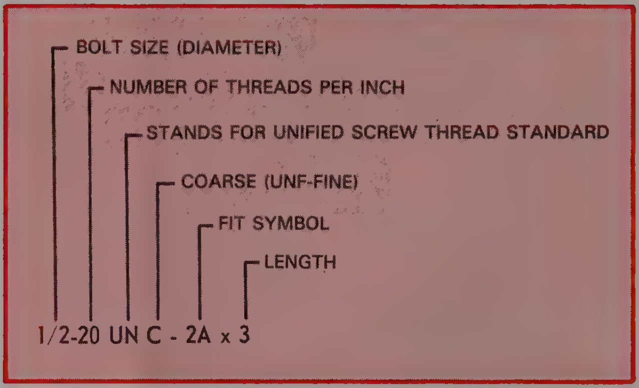

BOLT SIZE (DIAMETER)
NUMBER OF THREADS PER INCH
STANDS FOR UNIFIED SCREW THREAD STANDARD
COARSE (UNF-FINE)
FIT SYMBOL
LENGTH
1/2-20 UN C - 2A x 3

Fig. 3-17. Bolt descriptive symbols chart. By learning different markings, it will be much easier and faster when selecting correct replacement bolt. (Deere & Co.)

thread, class or fit, material, tensile strength, and wrench size needed. Look at Figs. 3-16 and 3-17.

HEAD MARKINGS

Steel bolts and cap screws are not all made of the same quality material nor is the tempering the same. Current practice utilizes markings on the bolt and screw heads to indicate the tensile strength of the fastener.

MAJOR DIAMETER

This is the widest diameter as measured from the top or crest of the threads on one side to the crest of those on the other. See Fig. 3-16.

MINOR DIAMETER

This diameter is determined by measuring from the bottom of the threads on one side to the bottom of the threads on the other. If you were to remove all traces of the threads, the diameter of the portion left would be the minor diameter, Fig. 3-16.

PITCH

Thread pitch is the distance between the crest of one thread to the same spot on the crest of the next thread. The smaller the pitch, the greater number of threads per inch. The pitch or number of threads per inch can best be determined by using a thread-pitch gauge as in Figs. 3-18 and 3-19.

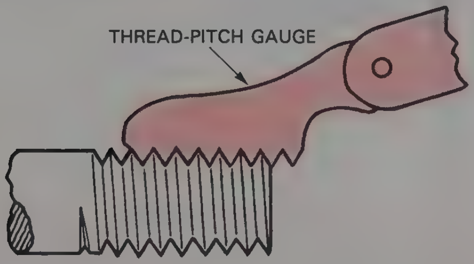


Fig. 3-18. Using a thread-pitch gauge to determine the number of threads per inch.

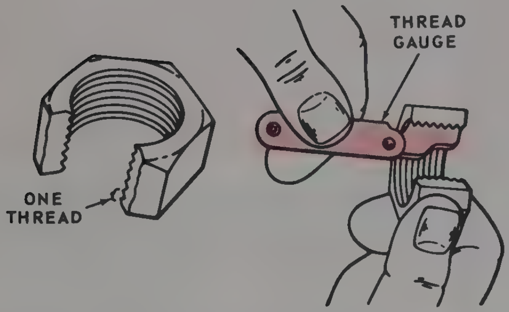


Fig. 3-19. Thread-pitch gauge being used to check nut for number of threads per inch. (Deere & Co.)

THREAD SERIES

Two series of threads in common use are the coarse (UNC - Unified National Coarse) and the fine (UNF - Unified National Fine). The coarse thread is generally used when screws are threaded into cast iron and aluminum. A fine thread will strip more easily in these materials.

Current practice is to use the coarse thread more widely than in the past. The coarse thread has a larger and less critical shoulder bearing area, screws in and out more quickly, and is less subject to stripping and galling.

Galling occurs when the threads rip particles of metal from each other, thereby damaging both threads. In severe cases, it causes the fastener to stick tightly.

As a bolt diameter increases, the size and pitch of the thread becomes greater. For example, UNC threads on a 1/4 in. diameter bolt are smaller and there are more threads per inch than UNC threads on a 1/2 in. bolt.

OTHER THREAD SERIES

Less commonly used are the UNEF (Unified National Extra Fine) and the 8, 12, and 16-thread series.

The UNEF is a finer thread than the UNF while the 8, 12, and 16-thread series are coarse threads for large bolts. For example, all bolts in the 8-thread series, regardless of diameter, have 8 threads per inch. The 12-thread series bolts have 12 threads per inch, etc.

Study the chart in Fig. 3-20. Note that screws under 1/4 in. in diameter are designated by number instead of fractional size.

NUT TERMINOLOGY

Nuts are used on bolts. They are usually hexagonal in shape. Nuts have a corresponding number of threads per inch and the same major thread diameter as the bolt. Wrench size (measured across flats) is very much standardized but does vary for special applications, Fig. 3-21.

CLASS OR FIT

Thread class indicates the operating clearance between the nut internal threads and the bolt external threads. Classes are divided into six categories: 1A, 1B, 2A, 2B, 3A, and 3B. The letter A indicates external threads (bolts, studs, screws) and the letter B indicates internal threads (nuts, threaded holes).

This, in effect, gives three classes. Number 1 class is a relatively loose fit and would be used for ease of assembly and disassembly under adverse conditions. Class 2 provides a fairly accurate fit with only a small amount of clearance, and is the class commonly used for automotive fasteners. Class 3 is an extremely close fit and is used where utmost accuracy is essential.

UNIFIED

The word UNIFIED, as used in Unified National Coarse and Unified National Fine, indicates that this thread conforms with thread standards used in the United States, Canada, and England.

LOCKING DEVICES

As screws, bolts, and nuts are subjected to vibration, expansion, and contraction, they tend to work loose. To prevent this, numerous locking devices have

Recommended for
AMERICAN NATIONAL SCREW THREAD PITCHES

COARSE STANDARD THREAD (N. C.)
Formerly U. S. Standard Thread

Sizes	Threads Per Inch	Outside Diameter at Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	64	.073	53	0.0595
2	56	.086	50	0.0700
3	48	.099	47	0.0785
4	40	.112	43	0.0890
5	40	.125	38	0.1015
6	32	.138	36	0.1065
8	32	.164	29	0.1360
10	24	.190	25	0.1495
12	24	.216	16	0.1770
1/4	20	.250	7	0.2010
5/16	18	.3125	F	0.2570
3/8	16	.375	5/16	0.3125
7/16	14	.4375	U	0.3680
1/2	13	.500	27/64	0.4219
9/16	12	.5625	31/64	0.4843
5/8	11	.625	17/32	0.5312
3/4	10	.750	21/32	0.6562
7/8	9	.875	49/64	0.7656
1	8	1.000	7/8	0.875
1 1/8	7	1.125	63/64	0.9843
1 1/4	7	1.250	1 7/64	1.1093

FINE STANDARD THREAD (N. F.)
Formerly S.A.E. Thread

Sizes	Threads Per Inch	Outside Diameter at Screw	Tap Drill Sizes	Decimal Equivalent of Drill
0	80	.060	3/64	0.0469
1	72	.073	53	0.0595
2	64	.086	50	0.0700
3	56	.099	45	0.0820
4	48	.112	42	0.0935
5	44	.125	37	0.1040
6	40	.138	33	0.1130
8	36	.164	29	0.1360
10	32	.190	21	0.1590
12	28	.216	14	0.1820
1/4	28	.250	3	0.2130
5/16	24	.3125	I	0.2720
3/8	24	.375	Q	0.3320
7/16	20	.4375	25/64	0.3906
1/2	20	.500	29/64	0.4531
9/16	18	.5625	0.5062	0.5062
5/8	18	.625	0.5687	0.5687
3/4	16	.750	11/16	0.6875
7/8	14	.875	0.8020	0.8020
1	14	1.000	0.9274	0.9274
1 1/8	12	1.125	1 3/64	1.0468
1 1/4	12	1.250	1 11/64	1.1718

SPECIAL THREAD (N. S.)

Sizes	Threads Per Inch	Outside Diameter at Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	56	.0730	54	0.0550
4	32	.1120	45	0.0820
4	36	.1120	44	0.0860
6	36	.1380	34	0.1110
8	40	.1640	28	0.1405
10	30	.1900	22	0.1570
12	32	.2160	13	0.1850
14	20	.2420	10	0.1935
14	24	.2420	7	0.2010
1/16	64	.0625	3/64	0.0469
3/32	48	.0938	49	0.0730
1/8	40	.1250	38	0.1015
5/32	32	.1563	1/8	0.1250
5/32	36	.1563	30	0.1285
3/16	24	.1875	26	0.1470
3/16	32	.1875	22	0.1570
7/32	24	.2188	16	0.1770
7/32	32	.2188	12	0.1890
1/4	24	.250	4	0.2090
1/4	27	.250	3	0.2130
1/4	32	.250	7/32	0.2187
5/16	20	.3125	17/64	0.2656
5/16	27	.3125	J	0.2770
5/16	32	.3125	9/32	0.2812
3/8	20	.375	21/64	0.3281
3/8	27	.375	R	0.3390
7/16	24	.4375	X	0.3970
7/16	27	.4375	Y	0.4040
1/2	12	.500	27/64	0.4219
1/2	24	.500	29/64	0.4531
1/2	27	.500	15/32	0.4687
9/16	27	.5625	17/32	0.5312
5/8	12	.625	35/64	0.5469
5/8	27	.625	19/32	0.5937
11/16	11	.6875	19/32	0.5937
11/16	16	.6875	5/8	0.6250
3/4	12	.750	43/64	0.6719
3/4	27	.750	23/32	0.7187
7/8	12	.875	51/64	0.7969
7/8	18	.875	53/64	0.8281
7/8	27	.875	27/32	0.8437
1	12	1.000	59/64	0.9219
1	27	1.000	31/32	0.9687

INCHES			DECIMALS	MILLI-METRES
		1/64	.015625	.3969
	1/32		.03125	.7937
		3/64	.046875	1.1906
1/16			.0625	1.5875
		5/64	.078125	1.9844
	3/32		.09375	2.3812
		7/64	.109375	2.7781
1/8			.125	3.1750
		9/64	.140625	3.5719
	5/32		.15625	3.9687
		11/64	.171875	4.3656
3/16			.1875	4.7625
		13/64	.203125	5.1594
	7/32		.21875	5.5562
		15/64	.234375	5.9531
1/4			.25	6.3500
		17/64	.265625	6.7469
	9/32		.28125	7.1437
		19/64	.296875	7.5406
5/16			.3125	7.9375
		21/64	.328125	8.3344
	11/32		.34375	8.7312
		23/64	.359375	9.1281
3/8			.375	9.5250
		25/64	.390625	9.9219
	13/32		.40625	10.3187
		27/64	.421875	10.7156
7/16			.4375	11.1125
		29/64	.453125	11.5094
	15/32		.46875	11.9062
		31/64	.484375	12.3031
1/2			.5	12.7000
		33/64	.515625	13.0969
	17/32		.53125	13.4937
		35/64	.546875	13.8906
9/16			.5625	14.2875
		37/64	.578125	14.6844
	19/32		.59375	15.0812
		39/64	.609375	15.4781
5/8			.625	15.8750
		41/64	.640625	16.2719
	21/32		.65625	16.6687
		43/64	.671875	17.0656
11/16			.6875	17.4625
		45/64	.703125	17.8594
	23/32		.71875	18.2562
		47/64	.734375	18.6531
3/4			.75	19.0500
		49/64	.765625	19.4469
	25/32		.78125	19.8437
		51/64	.796875	20.2406
13/16			.8125	20.6375
		53/64	.828125	21.0344
	27/32		.84375	21.4312
		55/64	.859375	21.8281
7/8			.875	22.2250
		57/64	.890625	22.6219
	29/32		.90625	23.0187
		59/64	.921875	23.4156
15/16			.9375	23.8125
		61/64	.953125	24.2094
	31/32		.96875	24.6062
		63/64	.984375	25.0031

Fig. 3-20. Typical screw thread tap size and decimal equivalent charts. (Deere & Co.)

been developed. These may be an integral part of the screw or nut, or may be a part placed under, through, and around the screw or nut. Epoxy cement is sometimes used.

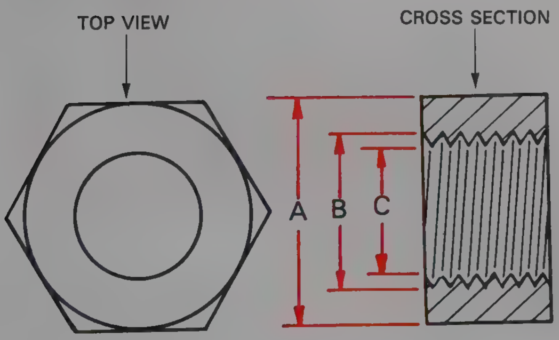


Fig. 3-21. Typical nut. A—Size across flats. B—Thread major diameter. C—Thread minor diameter.

SELF-LOCKING NUTS

Some nuts are designed to be self-locking or prevailing torque type. This is accomplished in various ways but all share the same principle. They create friction between the threads of the bolt or stud and the nut, Fig. 3-22.

In Fig. 3-22, nut A utilizes a collar of soft metal, fiber, or plastic. As the bolt threads pass up through the nut, they must force their way through the collar. This jams the collar material tightly into the threads, locking the nut in place.

In B, the nut upper section is slotted and the segments are forced together. When the bolt passes through the nut, it spreads the segments apart thus producing a locking action.

Detail C shows a single slot in the side of the nut. The slot may be forced open or closed during manufacture, thus distorting the upper thread. This will

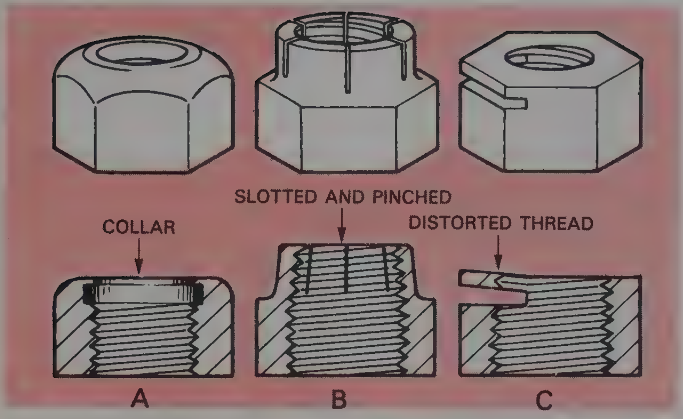


Fig. 3-22. Self-locking nuts. A—Soft collar type. B—Top section slotted and pinched together. C—Slot to distort upper thread area.

create a jamming effect when bolt threads pull nut threads back into alignment. A crimped nut is shown in Fig. 3-55.

SELF-LOCKING SCREWS

Some cap screws have heads that are designed to spring when tightened to produce a self-locking effect. Occasionally, the threaded end of a cap screw will be split and the halves slightly bent outward. When threaded into a hole, the halves are forced together. This creates friction between the threads.

LOCK WASHERS

A lock washer is used under the nut and grips both the nut and the part surface. The three basic designs are the internal, external, and the plain.

When using lock washers with die cast or aluminum parts, a plain steel non-locking washer is frequently used under the lock washer. It prevents damage to the part, Fig. 3-23.

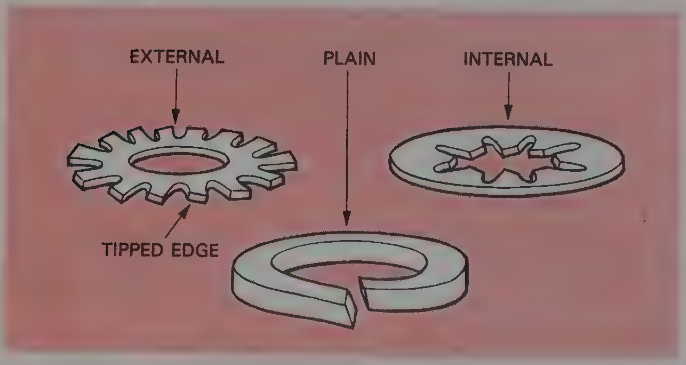


Fig. 3-23. Typical lockwashers. Not illustrated is another type that uses both internal and external fingers. Tipped edges provide gripping power in the "off" direction.

PALNUT

The palnut locking device is constructed of thin, stamped steel. It is designed to bind against the threads of the bolt when installed. In use, the palnut is spun down into contact with the regular nut (open side of palnut away from regular nut) with the fingers. Once firmly in contact with the nut, it is given one-half turn. Do not tighten beyond ONE-HALF TURN as the effectiveness of the palnut will be destroyed. The one-half turn draws the steel fingers towards the nut causing them to jam into the threads, Fig. 3-24.

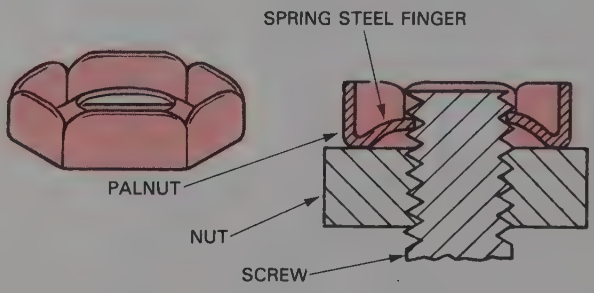


Fig. 3-24. Palnut. Half-turn jams steel fingers against threads.

COTTER KEY OR PIN

Cotter pins are used both with slotted and castle nuts as well as on clevis pins and linkage ends. Use as thick a cotter pin as possible. Cut off the surplus length and bend the ends as shown in Fig. 3-25. If necessary, they may be bent around the sides of the nut. Make certain that the bent ends will not interfere with some part.

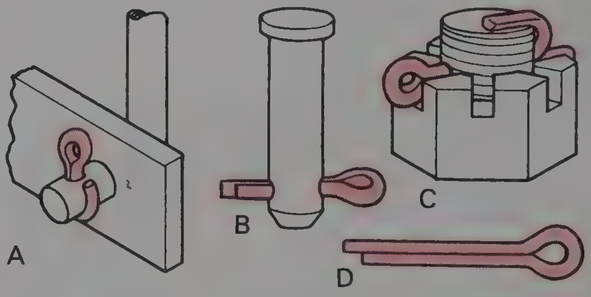


Fig. 3-25. Uses of cotter pin. A—Linkage. B—Clevis pin. C—Slotted hex nut. D—Typical cotter pin.

KEYS, SPLINES, AND PINS

Keys, splines, and pins are used to attach gears, sprockets, and pulleys to shafts so that they rotate as a unit. When a key or pin is used, the unit being attached to the shaft is generally fixed for no end to end movement. Splines will allow, when desired, longitudinal movement while still causing the parts to rotate together. In some cases pins are used to fix shafts in housings to prevent end movement and rotation, Fig. 3-26.

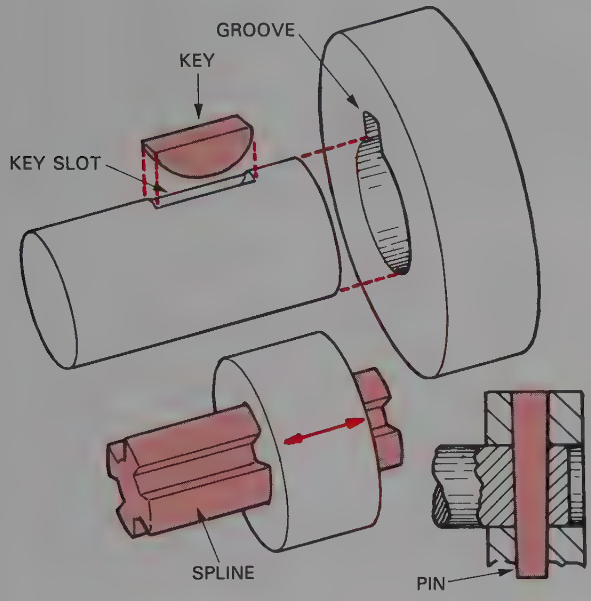


Fig. 3-26. Key, spline, and pin. Note that the spline allows end movement. The pin fixes the shaft to the housing, allowing no movement. The key is commonly referred to as a woodruff key or a half-moon key.

LOCKING PLATES AND SAFETY PINS

Locking plates are made of thin sheet metal. The plate is generally arranged so that two or more screws pass through it. The metal edge or tab is then bent up snugly against the bolt. Various patterns are used.

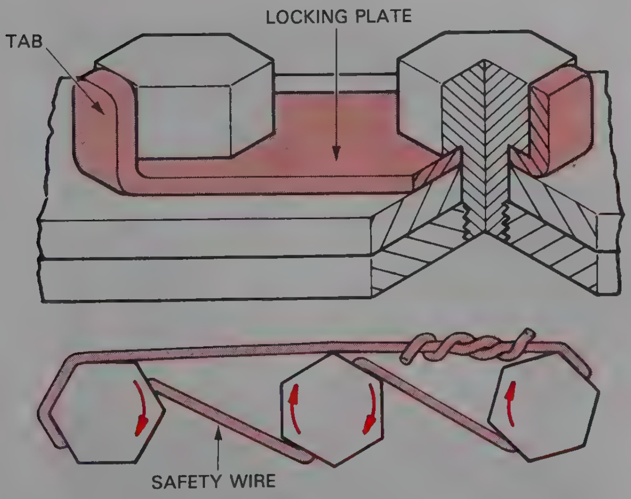


Fig. 3-27. Locking plate and safety wire. Tabs must be bent firmly against cap screw flat to prevent rotation.

Occasionally screws will be locked with safety wire (soft or ductile wire). The wire is passed from screw to screw in such a manner as to exert a clockwise pull.

Never reuse safety wire and always dispose of locking plates on which the tabs are fatigued (ready to crack), Fig. 3-27.

SNAP RINGS

Snap rings are used to position shafts, bearings, gears, and other similar parts. There are both internal and external snap rings of numerous sizes and shapes.

The snap ring is made of spring steel. Depending on the type, it must be expanded or contracted to be removed or installed. Special snap ring pliers are used.

Be careful when installing or removing snap rings because overexpansion or contraction will distort and ruin them. If a snap ring is sprung out of shape - throw it away. NEVER attempt to pound one back into shape. Never compress or expand snap rings any more than necessary. Above all, do not pry one end free of the groove and slide it along the shaft. This may ruin the ring, Fig. 3-28.

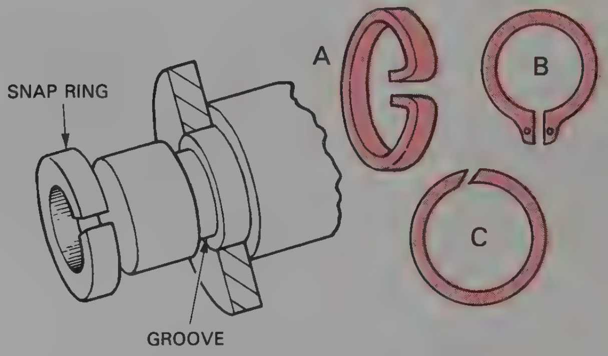


Fig. 3-28. Snap rings. A—Flat internal type. B—External. C—Round external. There are many shapes and sizes of rings.

SETSCREWS

Setscrews are used to both lock and position pulleys and other parts to shafts. The setscrew is hardened and is available with different tips and drive heads.

Keep in mind that setscrews are poor driving devices because they often slip on the shaft. When used in conjunction with a woodruff key, they merely position the unit. As a general rule, do not install any unit without a woodruff key.

When a setscrew is used, the shaft will usually have a flat spot to take the screw tip. Make certain this spot is aligned before running the screw up, Fig. 3-29.

RIVETS

Rivets are made of various metals, including brass, aluminum, and soft steel. They find many applications

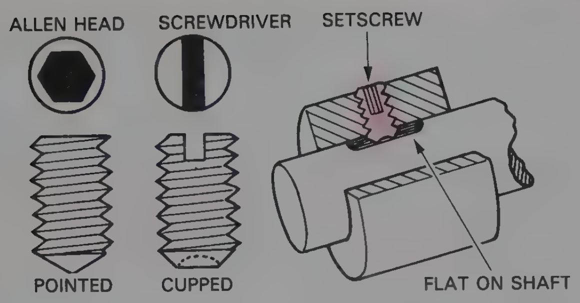

ALLEN HEAD
SCREWDRIVER
SETSCREW
POINTED
CUPPED
FLAT ON SHAFT

Fig. 3-29. Typical setscrews. Setscrews are hardened and they should be run up very tightly.

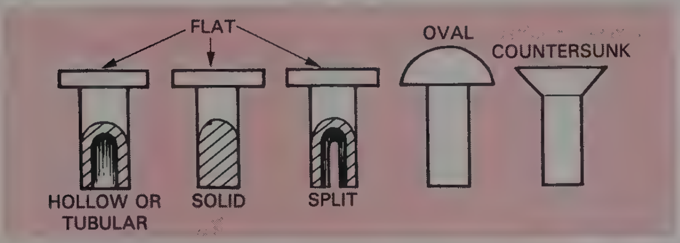

FLAT
OVAL
COUNTERSUNK
HOLLOW OR TUBULAR
SOLID
SPLIT

Fig. 3-30. Several types of rivets.

on an automobile. They are installed cold so that there is no contraction that would allow side movement between parts. Fig. 3-30 shows several types of rivets.

When using rivets, there are several important considerations. The two parts to be joined must be held tightly together before and during riveting. The rivet should fit the hole snugly. The rivet material must be in keeping with the job to be done. The rivet must be of the correct type (flat head, oval). The rivet should be set with a tool (rivet set) designed for the purpose. Fig. 3-31 illustrates the setting of a solid and a tubular rivet.

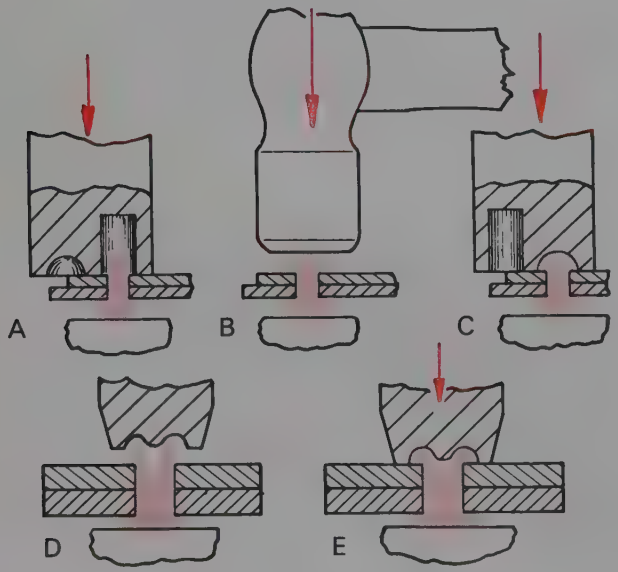


Fig. 3-31. Setting rivets. A—Pieces brought together and rivet seated. B—Rivet bulged. C—Rivet crowned and set. D—Set used for tubular rivet. E—Set forced down, crowning rivet as shown.

POP RIVETS

When one side of the work to be riveted is inaccessible, pop rivets may be used. They can be set from the outside and make blind rivets practical. Fig. 3-32 illustrates the use of one form of pop rivet.

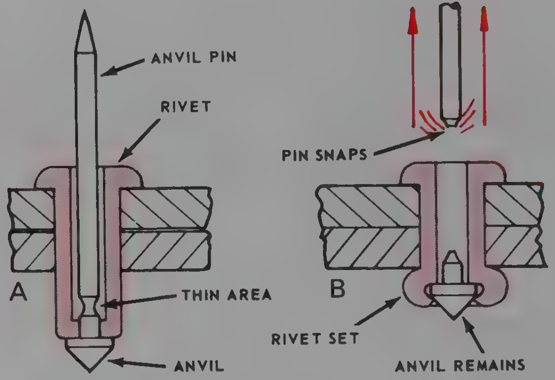

ANVIL PIN
RIVET
PIN SNAPS
A
THIN AREA
B
RIVET SET
ANVIL
ANVIL REMAINS

Fig. 3-32. Installing a pop rivet. A—Pop rivet in place. B—"Rivetool" has pulled anvil pin outward, pulling parts together, setting rivet and snapping off pin.

The pop rivet is inserted through the parts to be joined, a hand-operated setting tool, Fig. 3-33, is placed over the rivet anvil pin. When the handles are closed, the anvil pin is pulled outward. As the anvil is drawn outward, the rivet head is forced against the work and the hollow stem is set. The setting process draws the

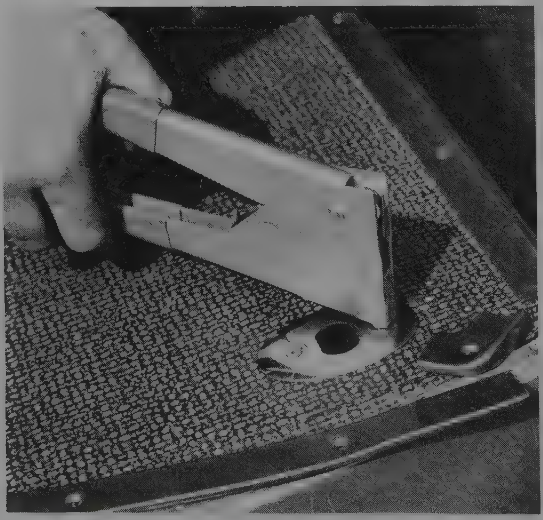


Fig. 3-33. Pop Rivetool in use.

two parts tightly together. Further pressure on the tool handles causes the anvil pin to snap off just ahead of the anvil. The anvil remains in the set area.

Fig. 3-33 shows a pop Rivetool being used to attach seat back trim.

OTHER FASTENERS

In addition to fasteners already discussed, there are numerous other specialized type fasteners such as hose clamps, C-washers, clevis pins, and spring lock pins. Many types are pictured in Fig. 3-55.

FASTENERS SHOULD BE TORQUED

To better understand the reason for, and the proper application of, controlled torque, the mechanic should be familiar with several important terms. Read the definitions which follow carefully. These terms will be used a great deal in this section.

TORQUE: Torque is a turning or twisting force exerted upon an object - in this case, the fastener. It is measured in inch-grams, inch-ounces, inch-pounds, foot-pounds, or newton-metres. See Fig. 3-34

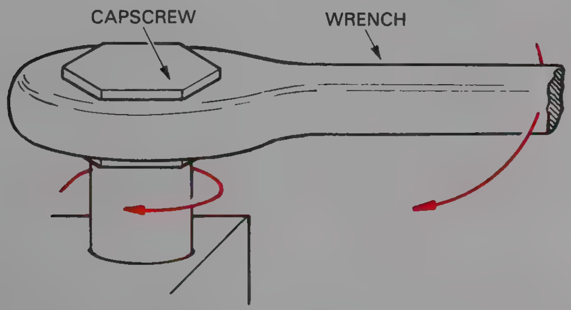


Fig. 3-34. Torque. Torque or a twisting force being applied to a cap screw with a box end wrench.

TENSION: Tension is a pulling force. When a cap screw is tightened, it actually stretches about .001 (0.025 mm) per 30,000 lbs. (13 500 kg) of tension, due to the tension being applied, Fig. 3-35.

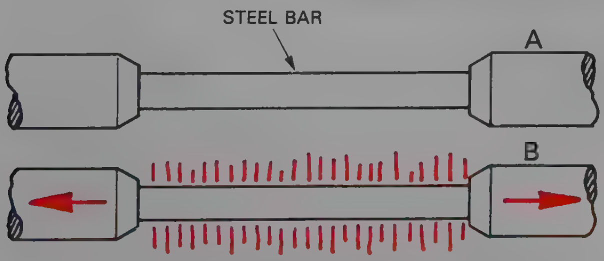


Fig. 3-35. Tension. A—Steel bar placed in jaws of a test machine. B—Jaws moving apart, creating a pull or tension on bar.

ELASTIC LIMIT: The amount or distance an object can be distorted (compressed, bent, stretched) and still return to the same dimension when the force is removed, Fig. 3-36.

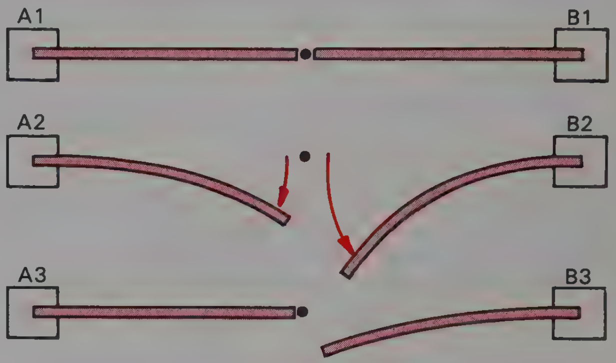


Fig. 3-36. Elastic limit. Bars in A1 and B1 at rest. Note that they are aligned with the black dot. In A2 the bar is bent within elastic limit and when pressure is removed it springs back to its normal (A3) position. Bar in B2 is bent beyond its elastic limit and when pressure is removed, the bar springs only part way back as in B3.

DISTORTION: The normal shape or configuration of an object being changed or altered due to the application of some force or forces, Fig. 3-37.

TENSILE STRENGTH: The amount of pull an object will withstand before breaking, Fig. 3-38.

RESIDUAL TENSION: The stress remaining in an elastic object that has been distorted and not allowed to return to its original dimension, Fig. 3-39.

ELASTICITY: The ability of an object to return, after distortion, to its original shape and dimensions once the distortive force has been removed, Fig. 3-40.

COMPRESSION: A force tending to compress or squeeze an object, Fig. 3-41.

COLD FLOW: This refers to the tendency of an object under compression to expand outward thus reducing its thickness in the direction of compression, Fig. 3-42.

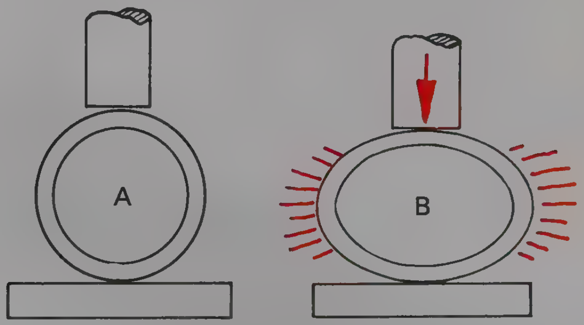


Fig. 3-37. Distortion. A—Hydraulic ram about to engage round steel ring. B—Pressure from ram bends or distorts ring.

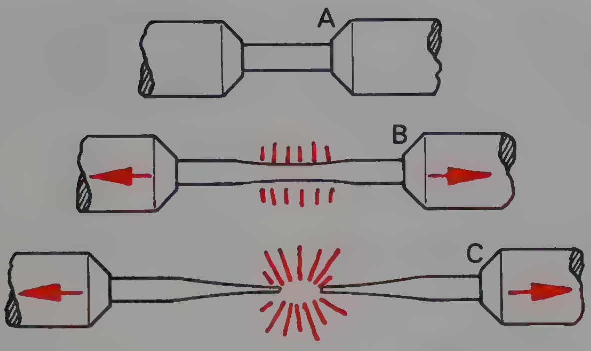


Fig. 3-38. Tensile strength. A—Bar of steel in a test machine. B—Heavy tension applied exceeding elastic limit, causing bar to stretch. C—Increased pull finally snaps bar as tension exceeds tensile strength.

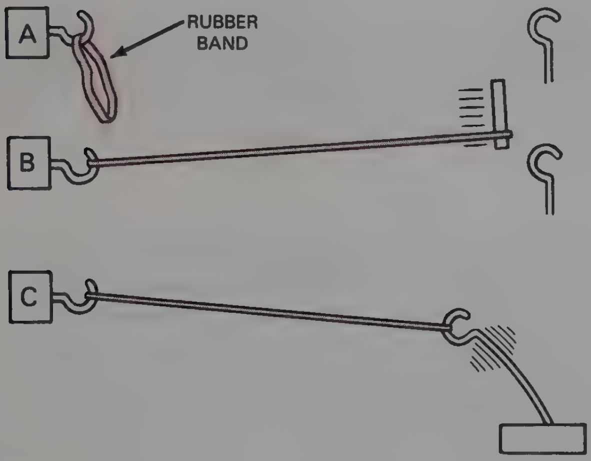


Fig. 3-39. Residual tension. A—Rubber band at rest; no residual tension. B—Band being pulled (distorted) out to engage spring steel hook. C—Band attempts to return to original dimensions, creating a pull (residual tension) and bending hook. Within its elastic limit, steel is more elastic than rubber.

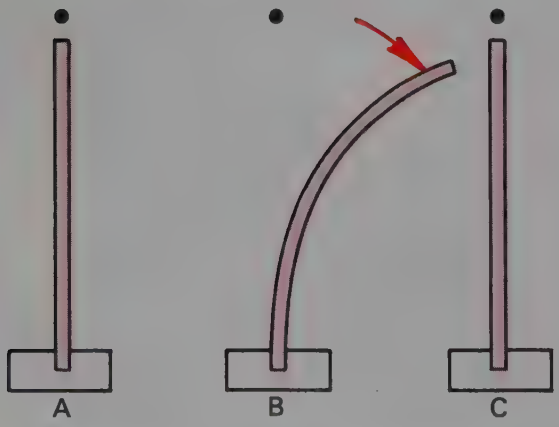


Fig. 3-40. Elasticity. A—Original position of bar. B—Bar deflected by pressure. C—No pressure, and bar returns to original position.

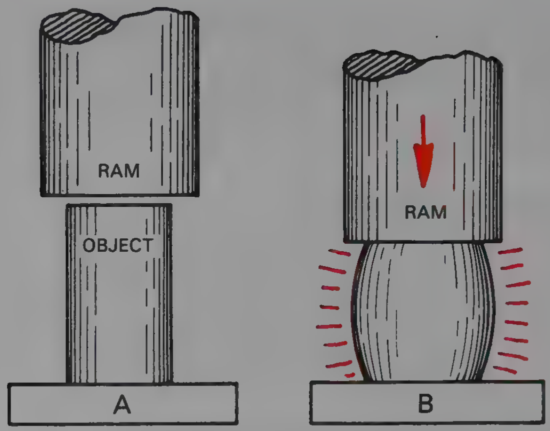


Fig. 3-41. Compression. A—Object at rest. B—Object under compression as ram builds up pressure.

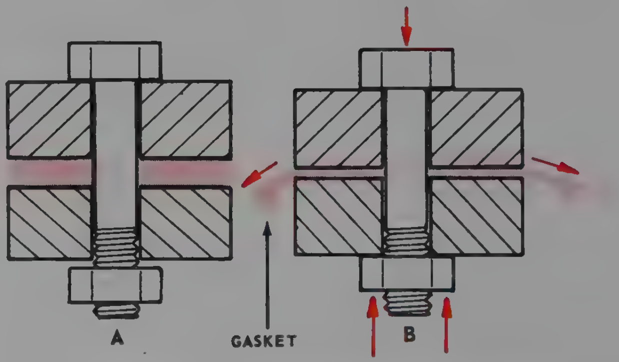


Fig. 3-42. Cold flow. A—The nut is not tight and there is no compressive force on gasket. B—Nut is tightened, compressing gasket and causing it to flow outward as thickness decreases.

HOOKE'S LAW: This law states that the amount of distortion (lengthening, shortening, bending, twisting), as long as it is kept within the elastic limits of the material, will be directly proportional to the applied force. This forms the basis for spring scales and torque wrenches, Fig. 3-43.

HIGH PRESSURE LUBRICANT: A lubricant that continues to reduce friction between two objects even when they are forced together under heavy pressure.

TORQUE FASTENERS

To understand the VITAL NECESSITY of torquing, we should first establish what we want to accomplish by tightening fasteners. Once this is clear, the reason for the use of a torque wrench becomes obvious.

We tighten fasteners to hold parts together. On the surface, this seems like a simple statement, but there is more here than meets the eye. When we say to hold parts together, we are, in effect, saying that once together, the parts should remain that way. When drawn together, the parts should not be distorted. The

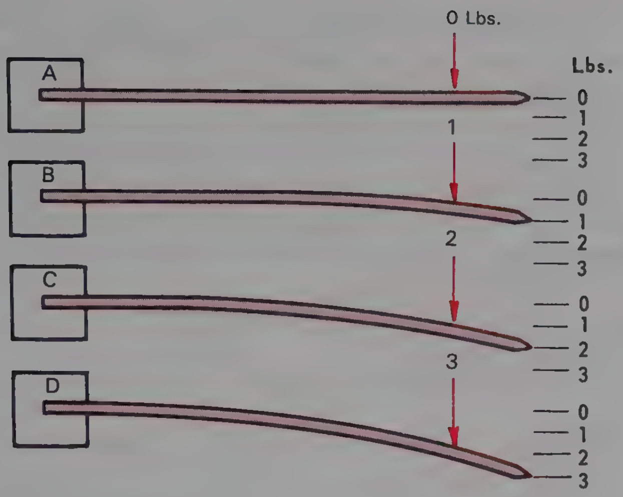


Fig. 3-43. Hooke's Law. Note that as weight on spring bar is increased, there is a proportionate movement on scale. This would continue until bar was deflected past its elastic limit.

fasteners should not be overtightened to the point they will fail in service. They must be tightened enough to prevent them from working loose, and perhaps being sheared or pounded apart. Oil, gas, and water leaks should not occur.

Let's assume that a "greenhorn" mechanic has just completely assembled an engine with a "guess and by gosh" method of tightening. Here is what COULD HAPPEN to the engine:

1. Cylinders out-of-round.
2. Connecting rod and main bearings egg shaped.
3. Cylinder head warped.
4. Valve guides forced out of alignment.
5. Camshaft bearing centerline out.
6. Crankshaft centerline out.
7. All engine components affected to some extent.

In addition, blown head gaskets, oil, water and air leaks, and broken connecting rods can plague the job.

Obviously, the amount of distortion will vary depending on the stresses set up within the assembly. Even at best, ring, piston, valve, and bearing wear will be accelerated. The job will fail in service long before it should.

PROPER FASTENER TENSION

The first thing to keep in mind is that all car manufacturers publish torque specifications. They should be followed. Each company has spent a great deal of time and money determining the fastener torque for their products that will give the best results. When using torque charts, make sure they pertain to the job at hand.

It has been found that for the vast majority of applications, a fastener should be tightened until it has built up a tension within itself that is around 50 to 60 percent of its elastic limit.

When the fastener has been drawn up to this point, it will not be twisted off. It will retain enough residual tension to continue to exert pressure on the parts and will resist loosening. Steel bolts and cap screws will stretch about .001 for each 30,000 pounds of tension. Like a rubber band, the tendency to return to their normal length provides continuous clamping effect.

FASTENER MATERIAL

As previously mentioned, most bolts and screws have radial lines on the head that indicate tensile strength. When replacing a fastener, use a quality at least equal to that originally used. You will find that the more critical the application (main bearing, connecting rod) the better the quality.

HOW FASTENER TORQUE IS MEASURED

To secure recommended torque, a measuring tool called a TORQUE WRENCH is a "must." The torque wrench will measure the torque (twisting force) applied to the fastener. Single round beam, double round beam, and single tapered beam type of torque wrenches are shown in Fig. 3-44.

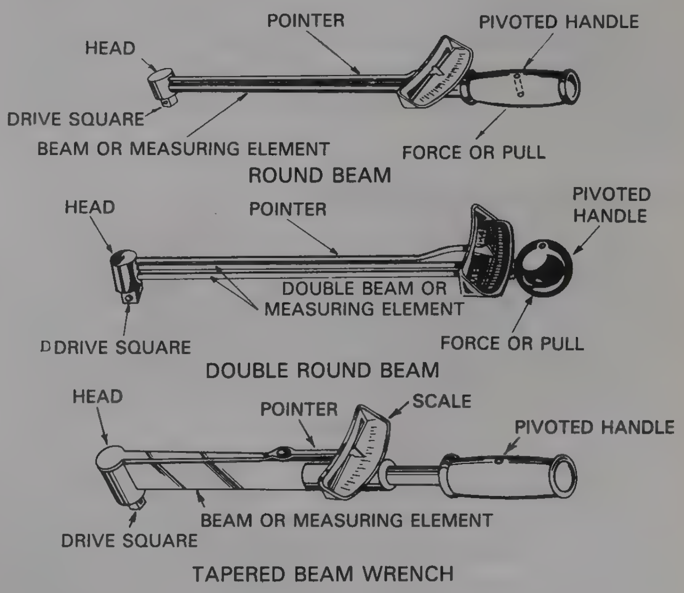


Fig. 3-44. Torque wrenches. These are all beam type wrenches, all widely used, durable, and accurate.

HOW A TORQUE WRENCH WORKS

The torque wrench uses Hooke's Law in its construction. By deflecting (bending) a steel beam (in some cases a coil spring), the relationship between the pull on the handle (torque) and the amount of beam deflection is readily established.

When the head is attached to the fastener and the handle is pulled, the flexible beam is bent. The pointer rod, being attached to the solid wrench head, is not bent. Since the scale is attached to the handle element, it follows the flexible beam, thus moving the scale under the pointer end. The scale is calibrated so that the operator can see how much torque is being applied.

If the center of pull on the handle is exactly one foot (305 mm) from the center of the head, a one pound (0.45 kg) pull on the handle would be ONE FOOT-POUND. One foot-pound equals twelve inch-pounds or 1.35 N·m.

Torque wrenches are available with a sensing device in addition to the scale. This warns the user that a preset torque has been reached without reading the scale. Various types of sensing devices such as a light or audible click are employed. When a torque wrench must be used in a position that makes reading the scale difficult or impossible, the sensing device is handy.

TORQUE WRENCH CALIBRATION

Torque recommendations can range from inch-grams, inch-ounces, inch-pounds to foot-pounds (newton-metres). For general automotive use, the inch-pound and foot-pound torque wrenches are in common use. REMEMBER: To convert foot-pounds to inch-pounds, multiply the foot-pounds by 12. To convert inch-pounds to foot-pounds, divide inch-pounds by 12. To convert foot-pounds to Newton-metres, multiply by 1.356.

TORQUE WRENCH RANGE

Torque wrenches are made in different sizes or ranges as well as in different calibrations. Ideally, the mechanic should have a 0-200 inch-pound (0-22.60 N·m), a 0-50 foot-pound (0-67.79 N·m), a 0-100 foot-pound (0-135.58 N·m), and a 150 foot-pound (203.37 N·m) torque wrench.

A torque wrench will produce BEST results if used somewhere near the middle half of its range. For example, a 0-100 foot-pound wrench would give the most accurate readings from around 25 to 75 foot-pounds. By having several ranges of wrenches, the mechanic will also find that this will offer several lengths. The shorter ones can be useful in restricted areas.

RANGE CAN BE ALTERED BY USING AN ADAPTER

Say you have a 0-100 foot-pound wrench available and the torque recommendation is 150 foot-pounds. This is obviously beyond the range of the wrench. It can still be used, however, through the use of an adapter to lengthen the effective range.

If the lever length (distance from center of wrench head to pivot point on handle) is 19 in. and you used an adapter bar of equal length, the torque being applied would be double that shown on the scale. If the lever was 9 1/2 in. or half as long as the lever length, the torque would be one and one-half times that shown on the scale. A handy formula to determine applied torque when using an adapter or extension is:

$$\frac{\text{Dial reading} \times (L + A)}{L}$$

$= \text{Torque applied to fastener.}$

(L) is length in inches from center of handle pivot to center of wrench head.
(A) is length in inches from center of wrench head to end of adapter. Must be measured parallel to centerline of wrench.

Fig. 3-45 shows three adapter setups. Notice that the effective length (L + A) is always measured parallel to the centerline of the wrench. REMEMBER: When using adapters or extensions, be certain of their exact length. Do not forget that length and torque are directly related, Fig. 3-45.

USING TORQUE WRENCH

After determining the proper torque and selecting a suitable range torque wrench, you are ready to proceed. Be sure to observe the following:

THREADS MUST BE CLEAN. The threads on the bolt or screw as well as those in the nut or hole, must be absolutely clean. Rust, carbon, and dirt will cause galling and improper tension. An accurate torque reading with dirty threads is impossible.

USE HIGH TEMPERATURE LUBRICANT. Unless the use of a lubricant is specifically forbidden (due to possibility of area contamination or need of a special sealant) always apply a high pressure lubricant to the threads and to the area where the nut or cap screw head contacts the part.

Refer to manufacturer recommendations to find out which high strength lubricant is suitable.

The use of lubricant will prevent or reduce the possibility of galling, seizing (sticking) or stripping. It will assure that the fastener torque has created the proper tension. It should be mentioned that the lubricant, while making the fasteners easier to remove at some future date, will not (if torqued properly) cause them to loosen in service. To the contrary, the increased tensioning for the same torque reading will actually cause the fastener to remain more secure.

USE PROPER LOCKING DEVICE

Unless a self-locking nut or cap screw is being used, make certain the recommended lock washer is in place.

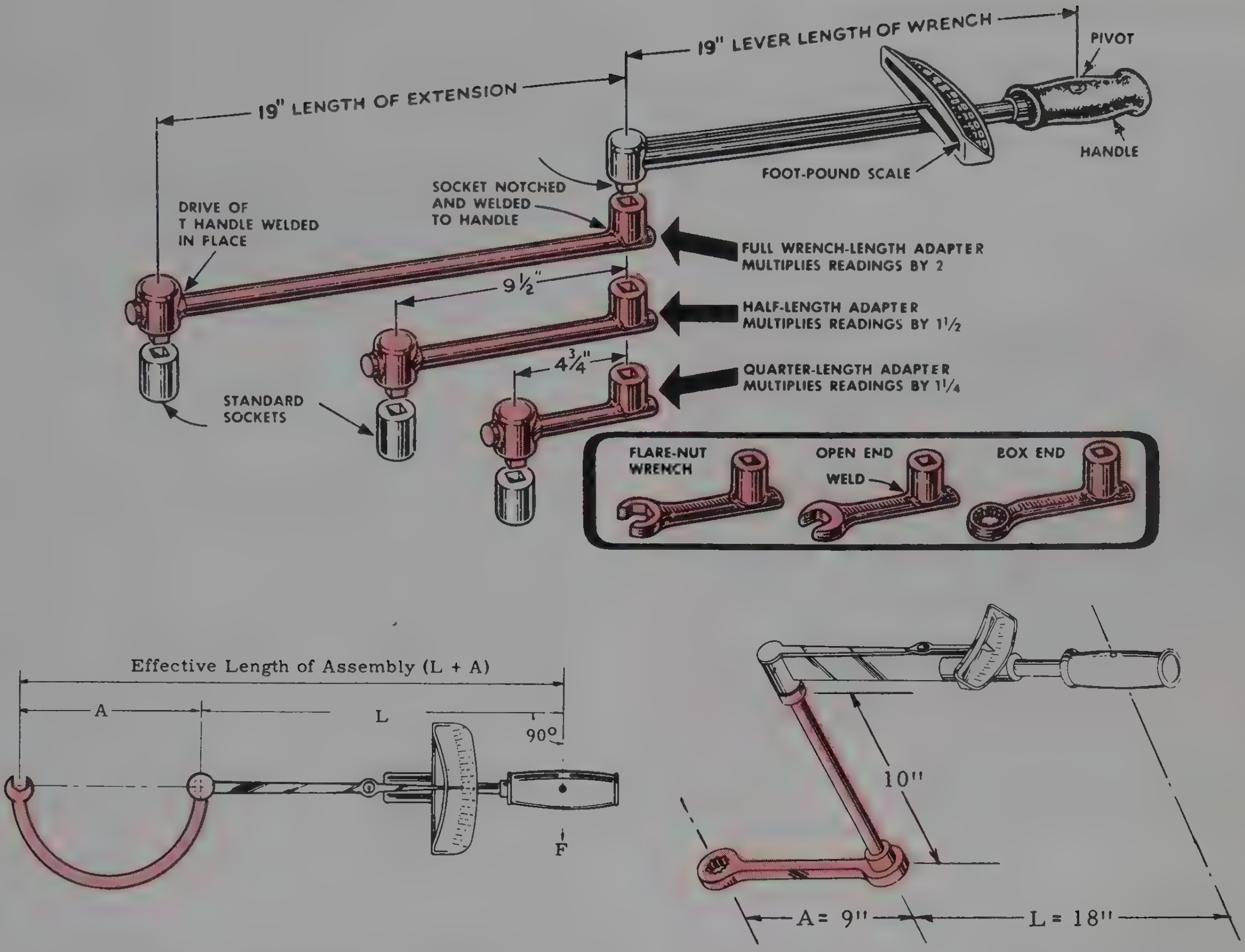

19" LEVER LENGTH OF WRENCH
PIVOT
19" LENGTH OF EXTENSION
HANDLE
FOOT-POUND SCALE
SOCKET NOTCHED AND WELDED TO HANDLE
DRIVE OF T HANDLE WELDED IN PLACE
FULL WRENCH-LENGTH ADAPTER MULTIPLIES READINGS BY 2
9½"
HALF-LENGTH ADAPTER MULTIPLIES READINGS BY 1½
4¾"
QUARTER-LENGTH ADAPTER MULTIPLIES READINGS BY 1¼
STANDARD SOCKETS
FLARE-NUT WRENCH
OPEN END
WELD
BOX END
Effective Length of Assembly (L + A)
A
L
90°
F
10"
A = 9"
L = 18"

Fig. 3-45. Torque wrench adapters. (Popular Science Monthly and P. A. Sturtevant Co.)

When running a fastener up against the softer metals, the use of a plain, flat washer between the lock washer and the part is often specified. This prevents the part from being "chewed" up and allows proper torquing without crushing the part.

CHECK FASTENERS

Be careful to check fasteners for correct diameter, threads per inch, and length. When installing cap screws, make certain they will not bottom (strike bottom of a threaded hole), in a blind hole (hole not drilled clear through part). Also, they must not protrude into a housing and damage a part of the unit.

REMEMBER: Stripped threads, broken screws, loose parts, and damaged units can result. Be careful!

In A, Fig. 3-46, the screw has bottomed leaving the part loose. Continued torquing could twist off the screw. In B, the screw protruded into case and damaged gear. In C, coarse thread screw, jammed into hole with fine threads, cracked part, Fig. 3-46.

Some fasteners serve an additional purpose. For instance, a head bolt or cap screw may be drilled for passage of oil, or a cap screw may have a threaded hole in the head to which another assembly is attached. Be careful to insert these fasteners in the correct place.

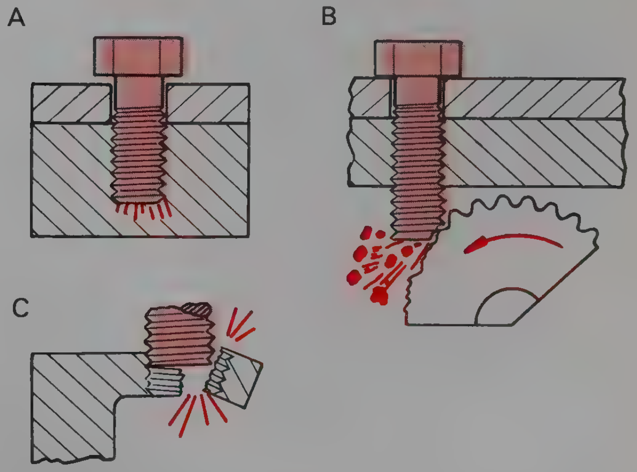


Fig. 3-46. Check fasteners! Make certain that fasteners are of correct diameter, length, and with sufficient thread of correct number of teeth per inch.

FOLLOW RECOMMENDED SEQUENCE

Where a number of fasteners are used to secure a part (such as a cylinder head), the proper sequence (order) of tightening should be followed. Fig. 3-47 illustrates the head bolt tightening sequence for one model engine. Always follow the manufacturer's specifications. See Figs. 3-47 and 3-48.

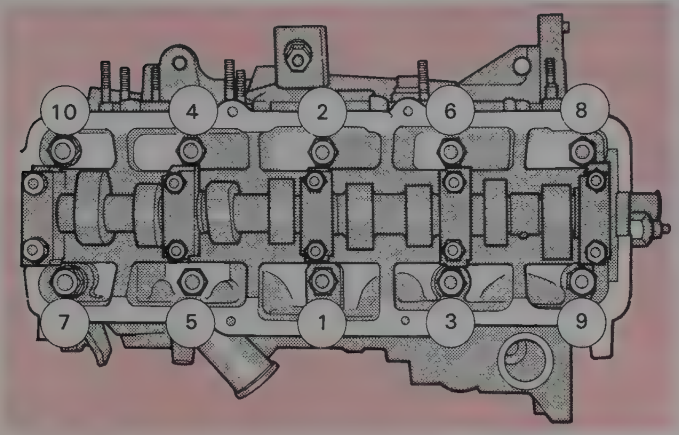


Fig. 3-47. Cylinder head bolt tightening sequence for one specific engine. (Chrysler)

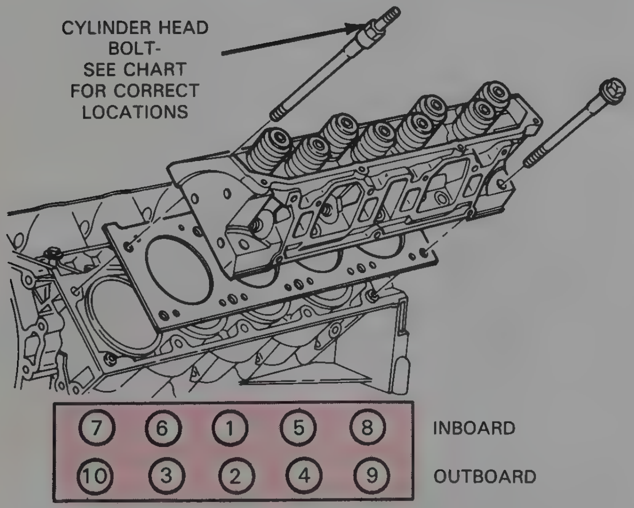


Fig. 3-48. Another cylinder head bolt tightening sequence. (Cadillac)

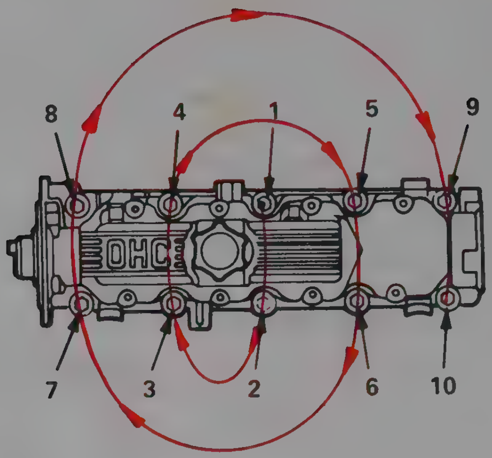


Fig. 3-49. Head bolt tightening sequence when no special recommendation is available. (Buick)

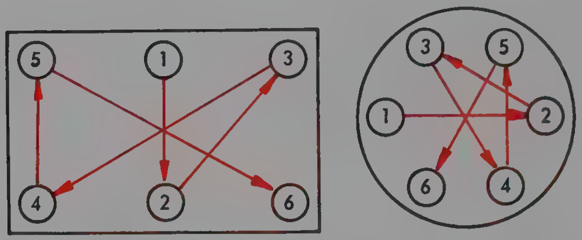


Fig. 3-50. Tightening bolts in crisscross sequence.

If no sequence chart can be obtained, it is usually advisable to start in the center and work out to the ends. The chart in Fig. 3-49 illustrates this technique.

On some assemblies, it is advisable to use a crisscross sequence. Always avoid starting in one spot and tightening one after another in a row. Remember that the object is to tighten the parts so that an even stress is set up. At the same time, a crisscross pattern will allow the parts to be drawn together so that their mating surfaces will contact evenly, Fig. 3-50.

Would a good fit be acquired if you followed the sequence shown in Fig. 3-51?

Quite obviously, if this sequence is followed, the two ends would be clamped down first. When the center bolts were tightened, the part could not flatten out. In order to flatten, it must spread outward. In order to do this, the ends must be free.

TORQUE IN FOUR STEPS

Always run the fasteners up snug (do not overtighten) with a regular wrench. Then, observe the following four steps.

1. Run each fastener, in the proper sequence, up to one-third of the recommended torque setting.

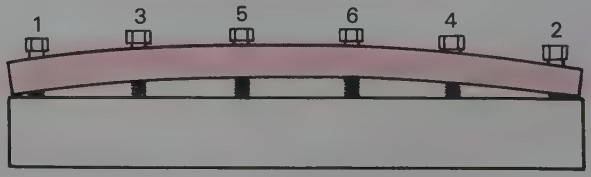


Fig. 3-51. Wrong sequence in tightening fasteners. This sequence would produce a very poor fit!

2. Repeat the process running up to two-thirds of the setting.
3. Repeat, running every fastener up to full torque.
4. This is a very important and frequently overlooked step - often to the embarrassment of the mechanic when the unit fails. REPEAT STEP THREE TO BE POSITIVE YOU HAVE NOT MISSED A FASTENER!

HOLDING THE TORQUE WRENCH

Where possible (it saves skinned knuckles), PULL on the wrench. Keep your hand on the handle. If using a pivoted handle, keep the handle from tipping in against the wrench. This is important as the pivot is where the pull should be for exact readings. Items A and B, in Fig. 3-52, show the correct hand position. In C, the mechanic has placed the right hand on one end of the handle tipping it and causing interference with wrench action. D shows an extension in place on the handle. This should never be done.

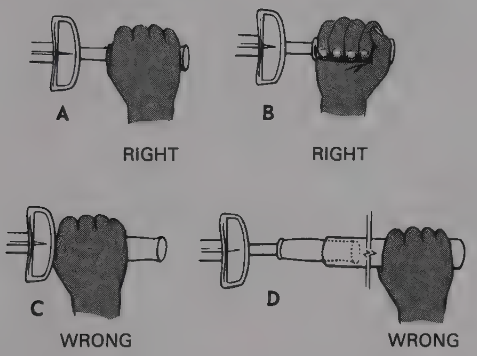


Fig. 3-52. Grasp the torque wrench properly.

PULLING THE WRENCH

When using a beam-type torque wrench, especially the single round beam, be careful to pull so that the beam is bent only in the direction of travel. If the wrench is bent up or down while pulling, the indicator point can drag on the scale, thus impairing the reading.

Place the palm of the left hand on the head of the wrench to counterbalance the pull on the handle. Allow your palm to turn with the wrench.

Fig. 3-53 illustrates the use of the left hand for balance. In this case, both an adapter and extension are being used.

STICKING

Quite often, when nearing full torque value, you will hear a popping sound. The fastener will seem to stick and stop turning. If you increase pressure on the wrench, it may run up to full torque without moving the fastener.

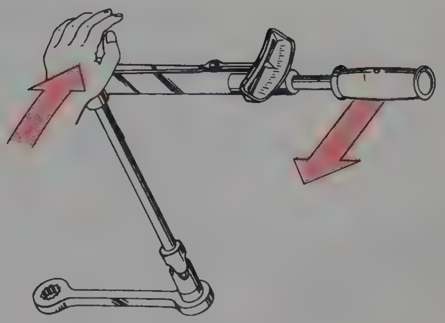


Fig. 3-53. Use the palm of the hand on the head of the wrench to balance the pull on the handle. (P. A. Sturtevant Co.)

You will find that when a fastener has stuck, the torque required to start it moving (break-away torque), is much higher than that required to keep it moving. This indicates that break-away torque is not a true fastener torque.

When sticking occurs, run the fastener in an off-direction (about one-half turn) until it breaks free. Then, with a smooth and steady pull, sweep the wrench handle around in a tightening direction. STOP when the required torque is reached.

RUN-DOWN TORQUE

Self-locking nuts, slightly damaged threads, or foreign material will cause the fastener to turn with some degree of resistance before it begins drawing parts together. This is called run-down torque.

If at all noticeable, add this run-down torque to the recommended torque. Determine run-down torque only during the last one or two turns of the fastener. When a fastener is first started, it may show considerable resistance. However, by the time it reaches bottom, this may have lessened or disappeared.

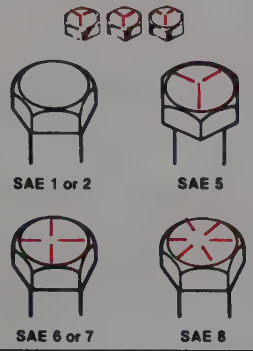
CAUTION: Whenever a fastener shows undue resistance - remove it and make sure it is the right length, diameter, and has the proper number of threads per inch.

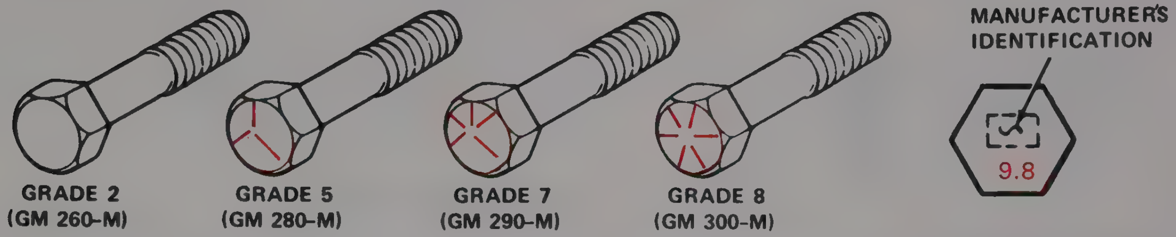
WHEN TORQUE RECOMMENDATIONS ARE NOT AVAILABLE

The mechanic should try to secure the car manufacturer's recommended torque for the specific job. If, however, it is not available, consult a chart such as the one in Fig. 3-54. You will note that by using the head markings and diameter, an approximate torque setting may be determined.

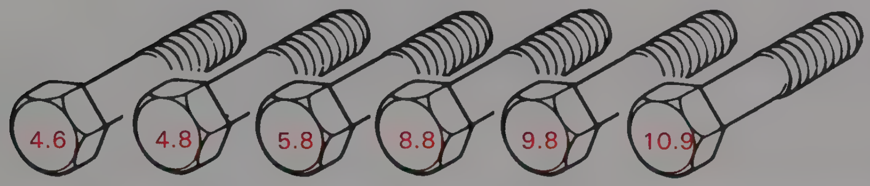
Keep in mind that if the fastener is threaded into aluminum, brass, or thin metal, the torque figures may have to be reduced to prevent stripping.

Standard Torque Specifications and Capscrew Markings Chart

CAPSCREW HEAD MARKINGS	CAPSCREW BODY SIZE Inches — Thread	SAE GRADE 1 or 2 (Used Infrequently)		SAE GRADE 5 (Used Frequently)		SAE GRADE 6 or 7 (Used at Times)		SAE GRADE 8 (Used Frequently)	
		Torque		Torque		Torque		Torque	
		Ft-Lb	N m	Ft-Lb	N m	Ft-Lb	N m	Ft-Lb	N m
Manufacturer's marks may vary. Three-line markings on heads shown below, for example, indicate SAE Grade 5. 	1/4-20 -28	5 6	6.7791 8.1349	8 10	10.8465 13.5582	10	13.5582	12 14	16.2698 18.9815
	5/16-18 -24	11 13	14.9140 17.6256	17 19	23.0489 25.7605	19	25.7605	24 27	32.5396 36 6071
	3/8-16 -24	18 20	24.4047 27.1164	31 35	42.0304 47.4536	34	46.0978	44 49	59.6560 66.4351
	7/16-14 -20	28 30	37.9629 40.6745	49 55	66.4351 74.5700	55	74.5700	70 78	94.9073 105.7538
	1/2-13 -20	39 41	52.8769 55.5885	75 85	101.6863 115.2445	85	115.2445	105 120	142.3609 162.6960
	9/16-12 -18	51 55	69.1467 74.5700	110 120	149.1380 162.6960	120	162.6960	155 170	210.1490 230.4860
	5/8-11 -18	83 95	112.5329 128.8027	150 170	203.3700 230.4860	167	226.4186	210 240	284.7180 325.3920
	3/4-10 -16	105 115	142.3609 155.9170	270 295	366.0660 399.9610	280	379.6240	375 420	508.4250 569.4360
	7/8- 9 -14	160 175	216.9280 237.2650	395 435	535.5410 589.7730	440	596.5520	605 675	820.2590 915.1650
	1- 8 -14	235 250	318.6130 338.9500	590 660	799.9220 894.8280	660	894.8280	910 990	1233.7780 1342.2420



B Customary (inch) bolts - Identification marks correspond to bolt strength - Increasing numbers represent increasing strength.



C Metric Bolts - Identification class numbers correspond to bolt strength - Increasing numbers represent increasing strength.

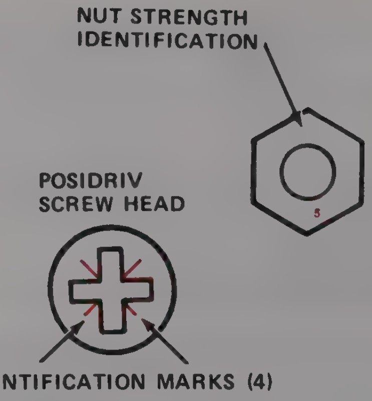


Fig. 3-54. Chart shows typical torque for cap screws with threads clean and dry. Reduce torque by 10 percent if threads are oiled; reduce by 20 percent if new, plated fasteners are used for various fastener grades. Always follow manufacturer's torque specifications for the exact job at hand. A—Cap screws, bolts and nuts are marked with either lines or numbers to indicate their relative strength. B—Customary (inch) bolt markings. Note that strength (grade) corresponds to number of lines. There are always two lines less than actual grade. C—Metric bolt markings. Higher grade (customary) or number (metric), greater the strength. (American Motors — General Motors)

RETORQUING

On some assemblies, such as cylinder heads and manifolds, all fasteners should be torqued after a certain period of operation. Cases such as these, and the proper interval, will be discussed in the textbook sections covering units to which they apply.

SUMMARY

The expert mechanic is vitally concerned with fastener design, application, and torque. He or she realizes that, to a great extent, the success or failure of the work depends upon the proper use of fasteners.

There are many types of fasteners: screws that thread into a part, bolts that pass through the parts and require nuts, studs that thread into the part, and also, nuts and sheet metal screws that cut their own threads.

The Unified National Coarse and the Unified National Fine thread series are commonly used. Threaded fasteners are identified by material, thread pitch, diameter, length of thread, type, etc. Steel bolts and screws use radial markings on the head to indicate material and tensile strength. See Fig. 3-55.

The removal of broken fasteners can cause difficulty unless done properly. Various methods are used.

When threads in a hole are damaged beyond repair, the hole may be drilled and tapped:

1. To the next suitable oversize and a larger cap screw installed.
2. To accept a threaded plug.
3. To accept a patented coil wire insert.

Snap rings, rivets, clevis pins, keys, and splines are nonthreaded fasteners.

Fasteners tend to loosen in service. Self-locking nuts, various lock washers, safety wire, locking plates, and cotter pins are some of the methods of keeping fasteners tight.

Fastener tension is important to prevent distortion,

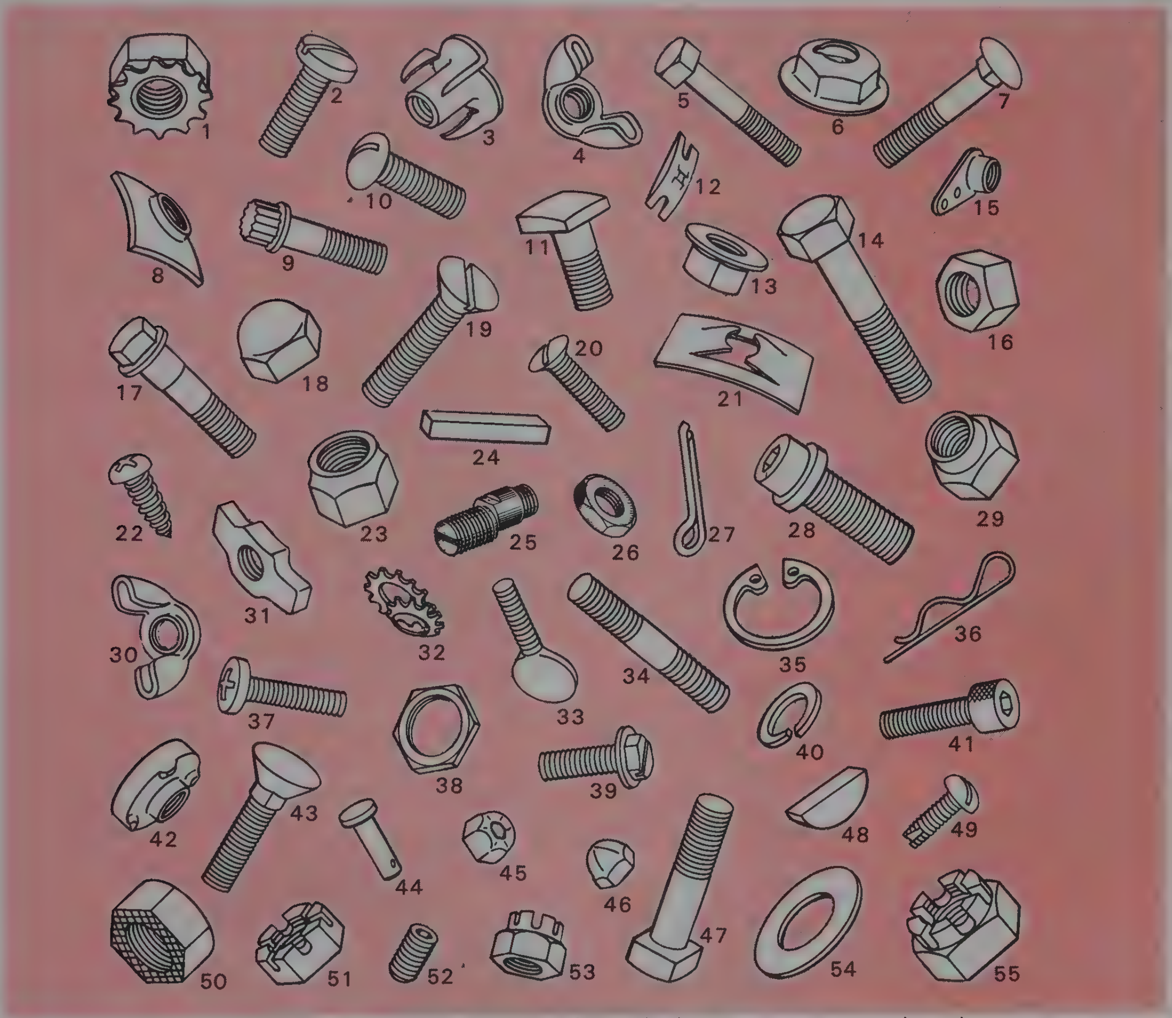


Fig. 3-55. An assortment of fasteners. Although terminology can vary somewhat, these are commonly used names: 1—Flange-lock nut. 2—Fillister head machine screw. 3—Barrel prong nut. 4—Wing nut. 5—Cap screw. 6—Palnut. 7—Carriage bolt. 8—Spring nut. 9—12-point head bolt. 10—Round head machine screw. 11—Askew-head bolt. 12—Single thread nut. 13—Flanged nut. 14—Cap screw. 15—Anchor nut. 16—Plain hex nut. 17—Hex flange screw. 18—Acorn (cap) nut. 19—Flat head screw. 20—Small flat head screw. 21—Speed nut. 22—Sheet metal screw. 23—Locking nut. 24—Key. 25—Offset (eccentric) stud. 26—Thin nut. 27—Cotter pin. 28—Socket head bolt. 29—Locking nut. 30—Wing nut. 31—Specialty nut. 32—Toothed lock washers. 33—Thumbscrew. 34—Stud. 35—Snap ring. 36—Spring lock pin. 37—Cross head machine screw. 38—Panel nut. 39—Flanged hex slotted head screw. 40—Split lock washer. 41—Hex socket head bolt. 42—Welded nut. 43—Plow bolt. 44—Clevis pin. 45—Open top acorn nut. 46—Closed top acorn nut. 47—Square head cap screw. 48—Woodruff key. 49—Self-tapping screw. 50—Serrated nut. 51—Slotted nut. 52—Set screw. 53—Castle nut. 54—Flat washer. 55—Castle nut.

to keep fasteners tight, and to prevent fastener failure. To provide proper tension, fasteners should be torqued.

Several types of torque wrenches are available for this purpose. They must be used properly.

Use high pressure lubricant on the threads and under the head or under the nut area on fasteners. Be certain the fastener is of the correct length, diameter, and has the proper number of threads per inch.

The proper sequence of tightening is very important. Always follow the manufacturer's recommended torque and sequence.

SUGGESTED ACTIVITIES

1. Take a sheet of paper. Wad it into a ball. Pull it back out and lay it on the table. If you were to try to press it out flat, where would you place your hands (fastener) first? In what direction (sequence) would you move them? Try it. How does this compare to tightening sequence?
2. Using a regular wrench, turn up several 3/8 in. screws to what you would guess to be 15 foot-pounds (20.34 N·m) of torque. Take a torque wrench and break them loose. Watch the scale carefully to determine the torque required to start them. Even though this will be different than true torque, how even were they? Was it close to 15 foot-pounds (20.34 N·m)?
3. Place two 1/4 in. bolts (one with six radial lines on head and other with none) of equal length in a vise. Keep them about two inches apart and with the same amount of material in the jaws. Run the vise up tightly. With a suitable torque wrench, turn each bolt until it snaps. Watch the scale carefully to determine torque at the moment of failure. Was the reading the same? If not, why? You will also note that it does not take much effort to snap a 1/4 in. bolt.

WOULD YOU USE A TORQUE WRENCH?

Suppose you are to be carried aloft 20 stories on a small steel platform. The platform is attached to the cable with ONE bolt. This bolt MUST be torqued to 150 FOOT-POUNDS. At 160 foot-pounds it will break in mid-air and at 140 foot-pounds it will slip. Anybody for a torque wrench?????

REMEMBER: YOUR REPUTATION AS A MECHANIC CAN WELL BE 20 STORIES OFF THE GROUND. KEEP IT SAFE. FOLLOW RECOMMENDED TORQUE AND USE A TORQUE WRENCH!

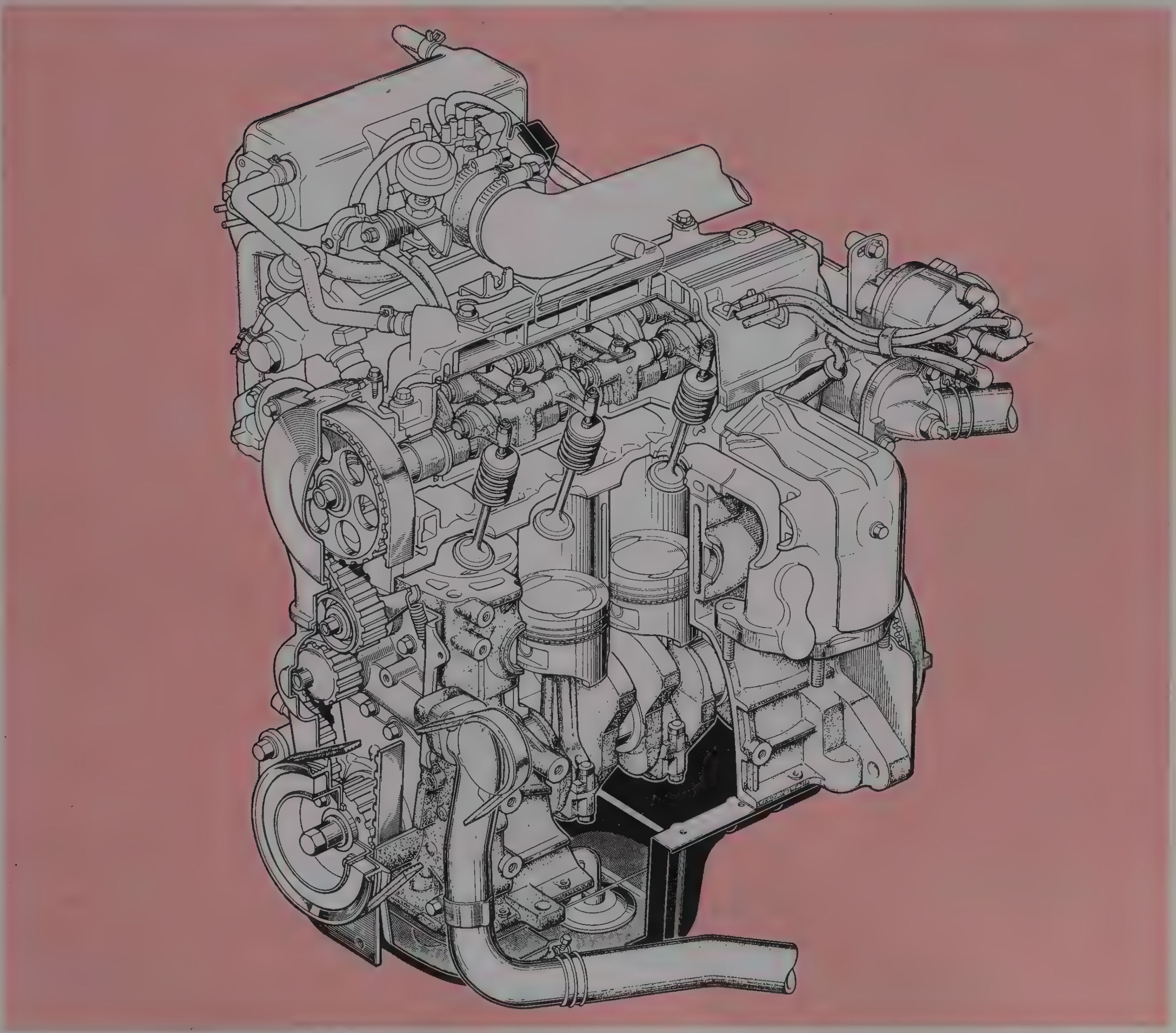
KNOW THESE TERMS

Machine screw, Sheet metal screw, Jam nut, Screw extractor, Penetrating oil, Heli-Coil, Hex, Castle, Pitch, Tensile strength, Head marking, Thread series, Lockwasher, Cotter key (pin), Snap ring, Setscrews, Torque, Hooke's Law, Torque wrench, Foot-pounds, Newton-metres, Tightening sequence, Run-down torque, Retorque.

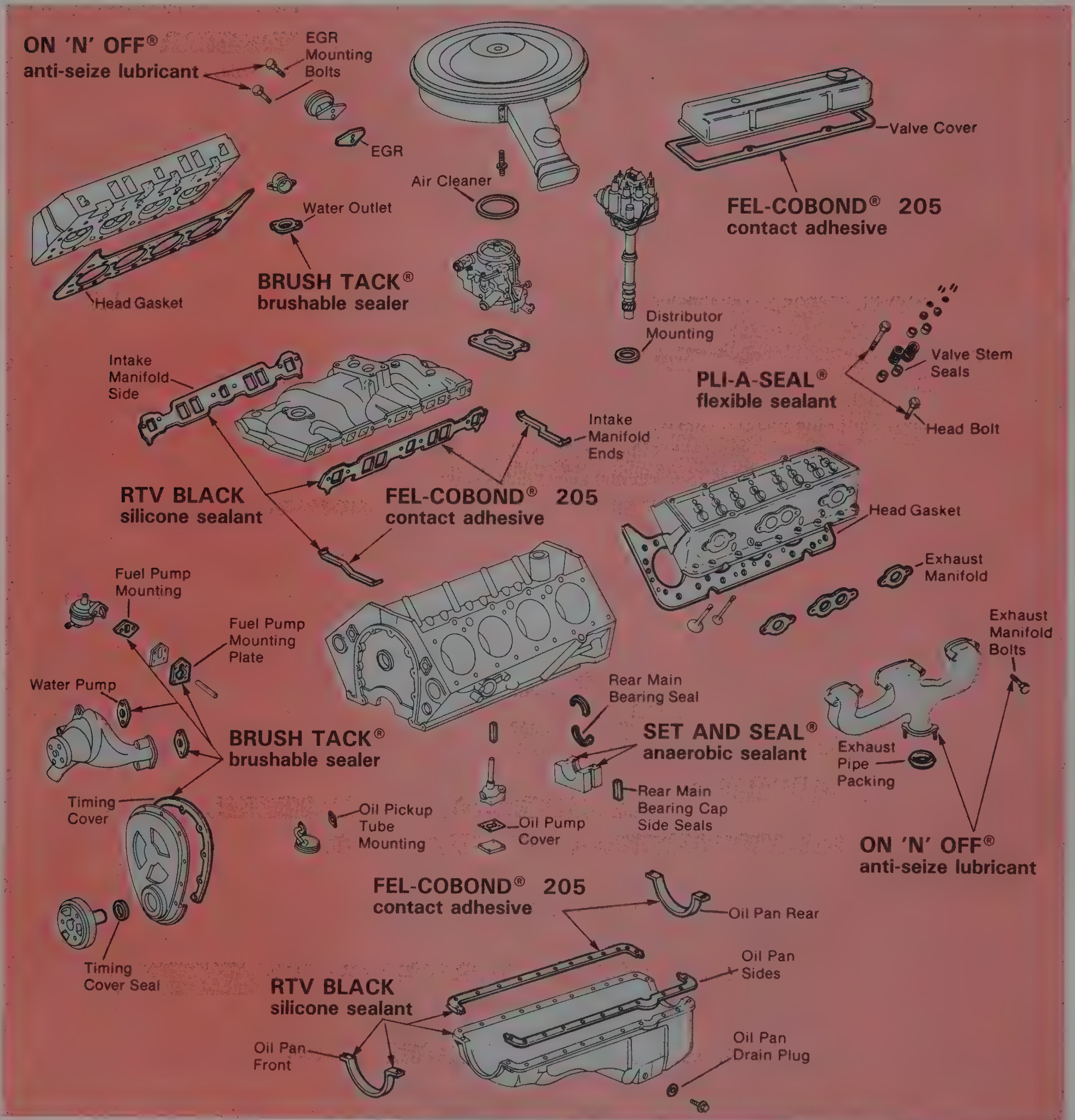
QUIZ - Chapter 3

1. Screws require the use of nuts. True or [✓ False]?
2. Sheet metal screws should be threaded into a hole about the size of their major diameter. True or [✓ False]?
3. Drilling is considered superior to punching holes in which sheet metal screws are to be inserted. True or [✓ False]?
4. A stud has threads on both ends.
5. Studs are best installed with pliers. True or [✓ False]?
6. Name four methods that may be used to remove broken screws or studs.
7. How can a stripped hole be repaired? Name three methods.
8. Three radial lines on the head of a bolt indicate that it has greater tensile strength than a bolt with six radial lines. True or [✓ False]?
9. Define the term major diameter.
10. How can the number of threads per inch on a screw be determined?
11. Define the term minor diameter.
12. Name the two popular thread series. VNC
13. When referring to thread class, a 2A would apply to a threaded nut with a fairly accurate fit. True or [✓ False]?
14. The class 2 fit is Commonly used for automobile fasteners.
15. Describe two kinds of self-locking nuts.
16. Name the three basic types of lock washers.
17. To use a palnut, run it down to the nut, open side away, and then give it half turn.
18. All fasteners have threads. True or [✓ False]?
19. A spline and a woodruff key both act as a driving mechanism or device. [✓ True] or False?
20. What is a lock plate?
21. Snap rings should NEVER be reused. True or [✓ False]?
22. A setscrew usually has a hexagonal head. True or [✓ False]?
23. When a rivet is used, the rivet should be Fit in the hole. The parts must be held together and a ______________ ______________ should be used.
24. Torque and tension are one and the same. True or [✓ False]?
25. Define the following: 1. Elastic Limit. 2. Distortion. 3. Tensile Strength. 4. Torque. 5. Tension. 6. Residual Tension. 7. Compression. 8. Elasticity. 9. Hooke's Law. 10. High Pressure Lubricant.

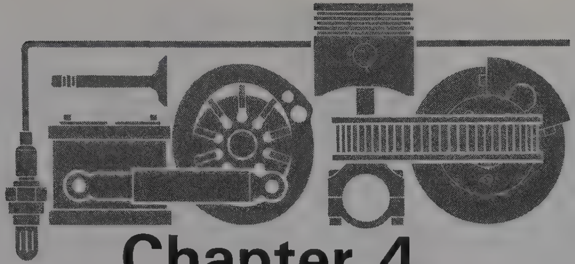
26. List three reasons for proper fastener tension.
27. Proper tension is best achieved by using a __________ __________ to tighten fasteners.
28. Why use lubricant on fastener threads?
29. Torquing should be in three initial steps. Fasteners drawn up to __1/3__ of recommended torque then to __1/3__ and finally to __torque__ torque.
30. What is the important fourth step in torquing?
31. Which of the following torque wrenches would you use to tighten a bolt to 50 foot-pounds?
    a. 0-200 inch-pound.
    b. 0-50 foot-pound.
    c. 0-100 foot-pound. ✓
    d. 0-200 foot-pound.
32. What effect will an adapter have on a torque wrench reading?
33. Describe how sticking during the final torquing should be handled.
34. To allow the user to torque fasteners when the position makes seeing the scale impossible, a __autobale__ device is used.
35. Always PUSH a torque wrench. True or False?
36. Once fasteners have been properly torqued, they will never need to be torqued again. True or False?
37. What is a torque chart?
38. Torque, for automotive use, is measured in ______________ ______________, ______________ ______________, or in metric ______________ ______________.



Fastener torque is very critical. Almost all of the fasteners you can see on this engine require an exact torque setting. The service manual will give torque specifications. (Mazda)


ON 'N' OFF®
anti-seize lubricant
EGR Mounting Bolts
EGR
Air Cleaner
Valve Cover
FEL-COBOND® 205
contact adhesive
Water Outlet
BRUSH TACK®
brushable sealer
Head Gasket
Distributor Mounting
Valve Stem Seals
PLI-A-SEAL®
flexible sealant
Head Bolt
Intake Manifold Side
Intake Manifold Ends
RTV BLACK
silicone sealant
FEL-COBOND® 205
contact adhesive
Head Gasket
Exhaust Manifold
Fuel Pump Mounting
Fuel Pump Mounting Plate
Exhaust Manifold Bolts
Water Pump
BRUSH TACK®
brushable sealer
Rear Main Bearing Seal
SET AND SEAL®
anaerobic sealant
Exhaust Pipe Packing
Timing Cover
Oil Pickup Tube Mounting
Oil Pump Cover
Rear Main Bearing Cap Side Seals
ON 'N' OFF®
anti-seize lubricant
FEL-COBOND® 205
contact adhesive
Oil Pan Rear
Timing Cover Seal
RTV BLACK
silicone sealant
Oil Pan Sides
Oil Pan Front
Oil Pan Drain Plug

An engine will require various gaskets, sealants, seals, and adhesives during assembly. To work on an engine, you must have adequate knowledge of this subject. Study the following chapter carefully; it is important. (Fel-Pro)



Chapter 4

GASKETS, SEALANTS, SEALS, AND ADHESIVES

After studying this chapter, you will be able to:

☐ Describe gasket construction, materials, and application.

☐ Explain the selection and use of sealants and adhesives.

☐ Describe the construction and installation of seals.

IMPORTANT AND WIDELY USED

Gaskets and seals are used throughout the car. They confine fuel, oil, water, and other fluids, in addition to air and vacuum, to specific units or areas. They keep dust, dirt, water, and other foreign materials out of various parts. They play an important part in the proper functioning and service life of all components.

Unfortunately, the importance of the proper selection, preparation, and installation of gaskets and seals is not always clearly understood. In addition to these duties, they effect torque and tension, part alignment and clearance, temperature, compression ratios, and lubrication. REMEMBER: THE FAILURE OF GASKETS, SEALANTS, SEALS, OR ADHESIVES CAN CAUSE EXTENSIVE DAMAGE AND EXPENSE. STUDY THE MATERIAL IN THIS CHAPTER CAREFULLY AND APPLY THE INFORMATION TO YOUR WORK!

GASKET

A gasket is a flexible piece of material, or in some cases, a soft sealant, placed between two or more parts. When the parts are drawn together, any irregularities (warped spots, scratches, dents) will be filled by the gasket material to produce a leakproof joint. See Fig. 4-1.

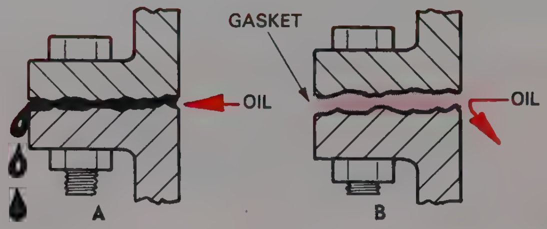


Fig. 4-1. Gasket stops leaks. A—Assembly has no gasket. Irregularities on part mating surfaces allow leakage. B—Same assembly is shown but with a gasket. Irregularities are filled and leak is stopped.

GASKET MATERIALS

Many materials are used in gasket construction. Steel, aluminum, copper, asbestos, cork, rubber (synthetic), paper, felt, and liquid silicone. The materials can be used singly or in combination.

Gasket material compressibility (how easily it flattens under pressure) varies widely. The gasket must compress to some extent to effect a seal. However, excessive compressibility will cause the gasket to extrude (cold flow outward and reduce thickness in direction of compression) or reduce its thickness beyond a specified point.

The gasket material selected will depend on the specific application, temperature, type of fluid to be confined, smoothness of mating parts, fastener tension,

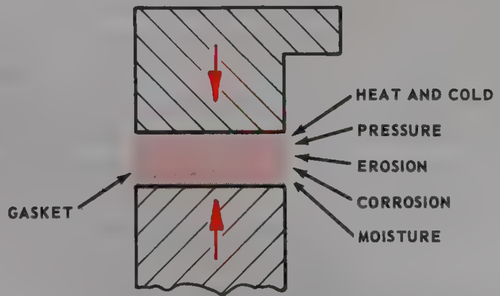


Fig. 4-2. Gasket must withstand many forces. Destructive forces shown, in addition to others not illustrated, are constantly attempting to destroy gasket.

pressure of confined fluid, material used in construction of mating parts, and part clearance relationship. All of these affect the choice of gasket material and design.

When constructing or selecting gaskets, give careful thought to these factors and choose wisely. Fig. 4-2 illustrates some of the destructive forces that the gasket must resist to function properly.

GASKET CONSTRUCTION

Some gaskets are of very simple construction. The engine top water outlet, for example, can use a medium thickness, chemically treated, fibrous paper gasket. Unit loading (pressure between mating parts) is light, temperature medium, coolant pressure low, and the coolant presents only mild problems, Fig. 4-3.

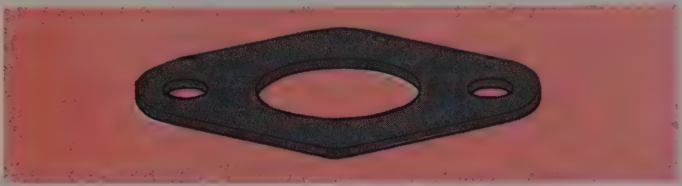


Fig. 4-3. Simple paper gasket. The paper is soft, tough, and water resistant.

As the sealing task becomes more difficult, gasket construction becomes more involved. The exhaust manifold to exhaust pipe gasket, where used, is more complex. Unit loading pressure is higher with corrosive flames, gases, and high temperatures attempting to destroy the gasket. This gasket, in two basic types, uses asbestos and steel in its construction, Fig. 4-4.

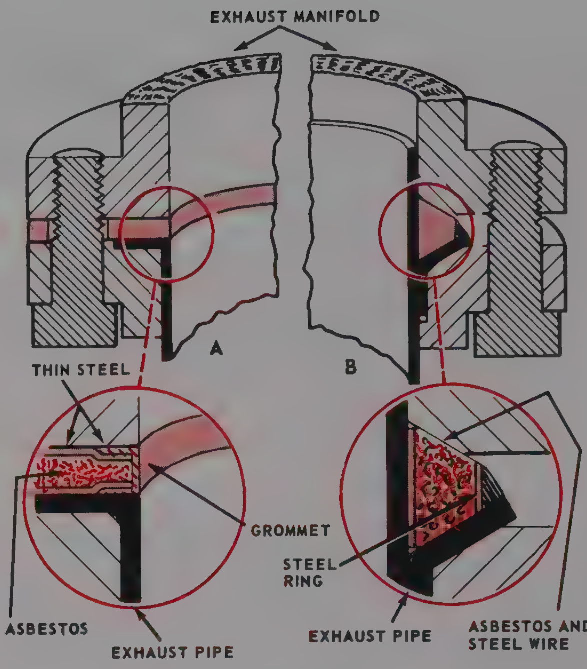


Fig. 4-4. Exhaust manifold gaskets. A—Gasket has an asbestos center with a thin steel outer layer. Note how inner edge is protected with a steel grommet. B—Gasket is made up of asbestos and steel wire. A thin steel outer ring can also be used for additional strength.

Perhaps the most complicated gasket, in terms of materials used and construction techniques, is the cylinder head gasket. Unit pressure is tremendous, combustion temperatures and pressures are very high. The head gasket must also seal against coolant, oil, corrosive gases, and thermal growth.

There are several basic designs in common use. Asbestos, steel, copper, and rubber may be used in their construction.

One type of multiple-layer gasket is shown in A, Fig. 4-5. A steel center core, perforated to produce tiny gripping hooks, is placed between two sheets of specially prepared asbestos. Steel or copper grommets are placed around the combustion chamber and coolant openings to assist in sealing. The entire gasket is then formed into a one-piece unit.

In B, Fig. 4-5, an asbestos center core is placed between two sheets of steel or copper. Note that the edges are rolled to produce a grommet.

The single layer beaded or corrugated type of gasket shown in C, Fig. 4-5, is popular on high compression engines. A single sheet of steel, around .020 in. (0.51 mm) thick, is stamped to produce a beaded edge around combustion chamber and fluid openings. This particular one is given an aluminum coating, about .001 in. (0.025 mm) thick, on both sides to assist in sealing and to prevent corrosion. This type of gasket requires accurate and smooth block-to-head surfaces. The aluminum coated steel gasket will withstand high temperatures and pressures quite successfully. In addition, it will not produce torque loss (gasket becoming thinner under continued fastener tension thereby reducing bolt tension and torque).

LOCALIZED UNIT LOADING

To produce higher unit loading around the combustion chambers or any other opening, a copper wire can be inserted between the top and bottom layers, near the edge. The remainder of the gasket tends to compress more readily. This creates the desired pressure around the opening, D, Fig. 4-5.

Another technique used to produce localized unit pressure or loading is shown in E, Fig. 4-5. This type uses a copper or soft iron grommet around the rolled edges.

Coolant and oil openings are sometimes sealed by placing special rubber or neoprene grommets in the gasket openings. These are highly resilient and maintain constant pressure around the openings, F, Fig. 4-5.

Several other techniques employed in head gasket

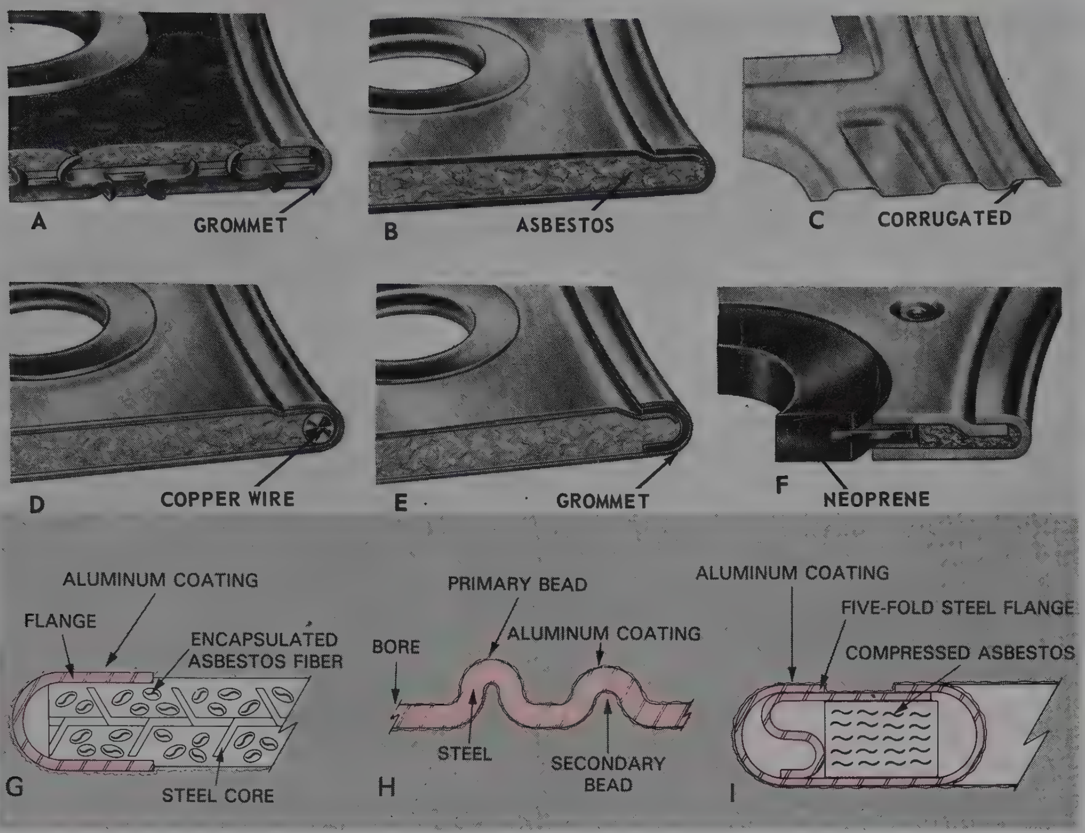

A
GROMMET
B
ASBESTOS
C
CORRUGATED
D
COPPER WIRE
E
GROMMET
F
NEOPRENE
ALUMINUM COATING
FLANGE
ENCAPSULATED ASBESTOS FIBER
G
STEEL CORE
PRIMARY BEAD
BORE
ALUMINUM COATING
STEEL
SECONDARY BEAD
H
ALUMINUM COATING
FIVE-FOLD STEEL FLANGE
COMPRESSED ASBESTOS
I

Fig. 4-5. Some of the different methods employed in head gasket construction. (Victor, McCord)

design and construction are shown in G, H, and I, Fig. 4-5. A soft-seal surface composition gasket is shown in G. Note the use of encapsulated asbestos fiber and an aluminum coating over the outside surface for better sealing. The use of a sealer is recommended with this gasket. An embossed steel type (similar to C), also called "shim" gasket, is pictured in H. It is produced from sheet steel approximately .020 in. (0.51 mm) in thickness. It provides good strength in the bead area and fine sealing capabilities when properly installed. The use of a sealer is advised. This type gasket is very popular today on original equipment engines.

Fig. 4-5, I, is a metal clad, sandwich gasket. It is constructed of sheet steel wrapped around a compressed asbestos center. The steel is coated with aluminum on the outside to aid in sealing. Use of a sealer is also advisable.

Fig. 4-6 shows sheets used to make a cylinder head gasket.

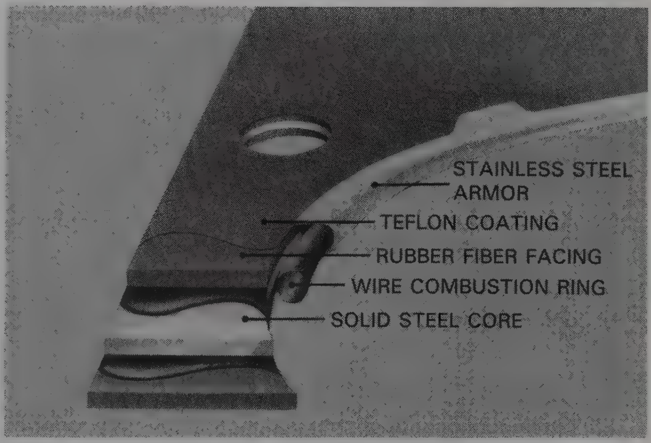

STAINLESS STEEL ARMOR
TEFLON COATING
RUBBER FIBER FACING
WIRE COMBUSTION RING
SOLID STEEL CORE

Fig. 4-6. One type of head gasket construction. (Fel-Pro)

GASKETS OFTEN COME IN SETS

Gaskets are often ordered in sets. For engine work, gaskets are available in a HEAD SET (includes all gaskets necessary to remove and replace head or heads), VALVE GRIND SET (includes all gaskets necessary in doing a valve grind job), and OVERHAUL SET (includes all gaskets necessary in doing a complete engine overhaul). See Fig. 4-7. Sets for transmission, carburetor, and differential are available separately. Single gaskets for some specific parts are also available. Gasket sets also include necessary oil seal replacements.

GASKET INSTALLATION TECHNIQUES

After selecting a gasket material and construction, there are a few important installation considerations. Regardless of the suitability of the gasket, if not properly installed, it will fail.

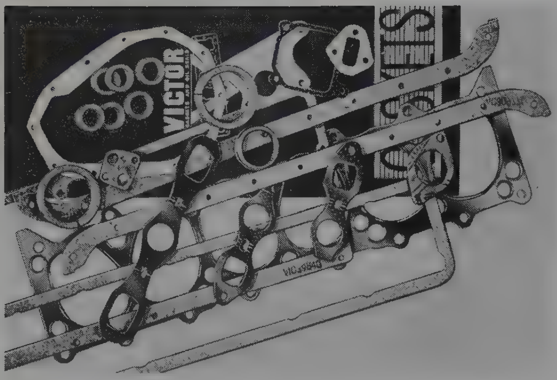


Fig. 4-7. Engine overhaul gasket set. This set is for a Chevrolet six cylinder. (Victor)

NEVER REUSE A GASKET

Once a gasket has been in service, it will loose a great deal of its resiliency. When removed, it will not return to its original thickness. If reused, it will fail to compress and seal properly. Gasket cost, as related to part and labor costs, is small. The professional mechanic does not even consider using old gaskets. Fig. 4-8 demonstrates how the use of old gaskets will produce leaks.

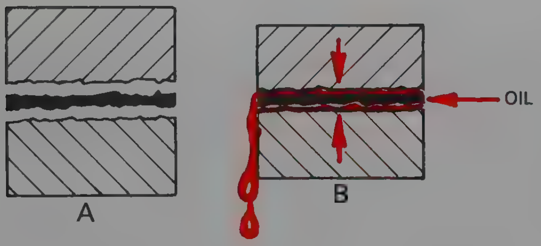


Fig. 4-8. Used gaskets will not work! A—Used gasket is positioned. B—When the parts are tightened, old, hardened gasket cannot compress and fill irregularities. The results: LEAKS!

CHECK MATING SURFACES

After cleaning, inspect mating surfaces for damage. If machined, a 90-110 microinch finish is needed for proper sealing. Refer to Fig. 4-9.

CHECK GASKET FOR PROPER FIT

Place the gasket on the part to determine if it fits properly. On the more complicated setups, such as cylinder head gaskets, make certain the gasket is right side up, proper end forward, and that bolt, coolant, and other openings are clear and in proper alignment. Occasionally you may notice that the gasket coolant openings may be slightly larger or smaller than the ports in the block or head. This gasket may be designed to fit several models or to restrict or improve coolant circulation. Check out these situations carefully.

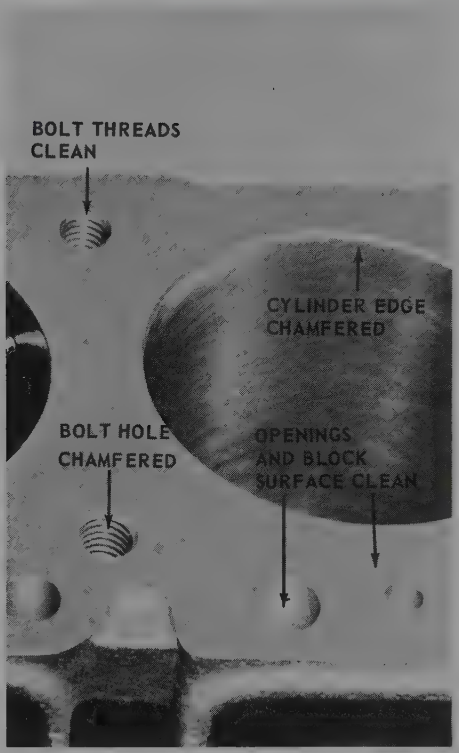


Fig. 4-9. Check mating surface. Notice that cylinder block surface is clean, smooth, and that all openings are clean. (Chevrolet)

Head gaskets for the left and right bank on some V-8 engines are interchangeable. Others are not. Many head gaskets have the word TOP and occasionally the word FRONT stamped on them, Fig. 4-10.

SOME GASKETS TEND TO SHRINK OR EXPAND

Paper and cork type gaskets that have been stored for some time tend to either lose or pick up moisture depending on storage conditions. Loss of moisture can cause them to shrink. Excess moisture can expand them. In either case, when checking for proper fit, they will show signs of misalignment.

This condition can be corrected by soaking shrunken gaskets in water for a few minutes or by placing expanded gaskets in a warm (not over 150-200°F or 65.6-93.4°C) spot. Check them occasionally to prevent overdoing the treatment, Fig. 4-11.

CHAMFERING SCREW HOLES MAY BE NECESSARY

When installing head gaskets, examine the screw holes in the block. If the threads run right up to the very top, it is a good idea to chamfer them lightly.

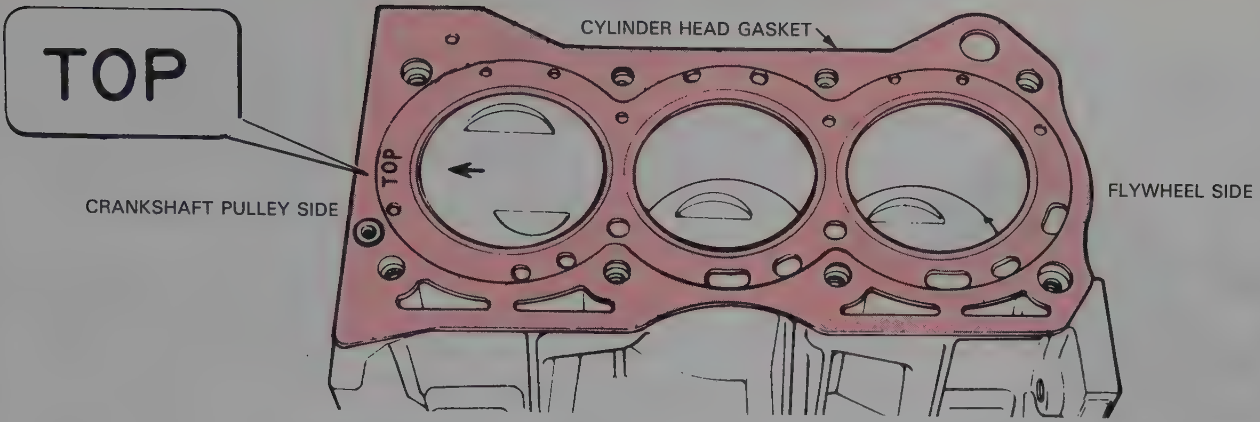


Fig. 4-10. Cylinder head gasket is marked "top" and must be installed so that this word faces technician. All openings must align for proper fit. (Chevrolet)

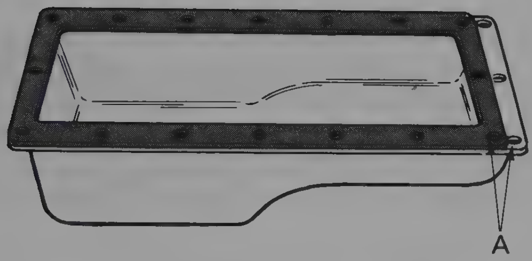


Fig. 4-11. Pan gasket has shrunk. Gasket has dried out, producing shrinkage. Note in A how screw holes fail to match. Soaking will salvage this gasket.

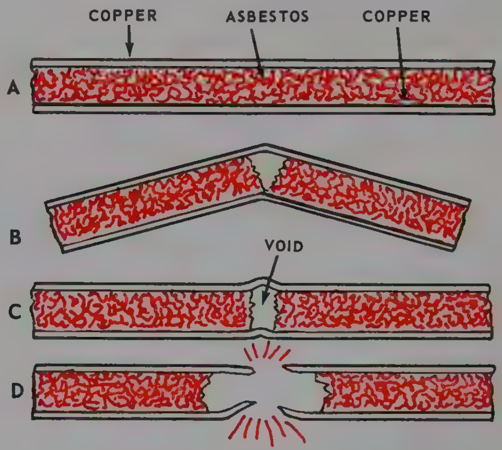


Fig. 4-12. Creased gasket. A—Multiple-layer head gasket. B—Gasket has been creased and the center packing pulled apart. C—Gasket straightened producing void. D—Gasket has "blown" in service.

Then, run the proper size tap in and out of the holes. The chamfer prevents the top thread from being pulled above the block surface. Blow out the holes with compressed air. WHEN USING AN AIR HOSE FOR CLEANING, ALWAYS WEAR GOGGLES. SMALL PARTICLES CAN BE THROWN WITH GREAT FORCE - BE CAREFUL!

EACH GASKET SHOULD BE CHECKED

Carefully inspect the gasket itself for dents, dirt, cracks, or folds. A minor crease in a cork or paper gasket usually does not render it useless. However, when checking head gaskets, BEWARE of ALL creases. If bent sharply, do not attempt to straighten it. The inner layer may be separated and cause failure. A gentle bend will not ruin the gasket - sharp kinks and creases will. Fig. 4-12 illustrates what happens when a multiple-layer head gasket is creased and then straightened.

MAKING A GASKET

A simple paper or combination cork and rubber gasket can be made. First, trace the pattern. Then, cut with scissors or lay the gasket material on the part and gently tap along the edges with a brass hammer. Screw holes can also be tapped lightly with the peen end of the ball peen hammer. Do not tap hard enough to damage the threads. Gasket punches can also be used to make neat screw holes. It will help hold the material in place if you tap out the corner holes and start these screws before tapping around the edges, Fig. 4-13.

HANDLE GASKETS WITH CARE

Gaskets should be stored flat, in their containers, and in an area where they will not be bent or struck. Storage space should not be subjected to extremes of temperature or humidity. Handle gaskets carefully. Do not attempt to force them to fit. If a gasket is accidentally cracked or torn - throw it away.

USE OF SEALANTS

A new, properly installed gasket will usually produce a leakproof joint. However, mating surfaces are not

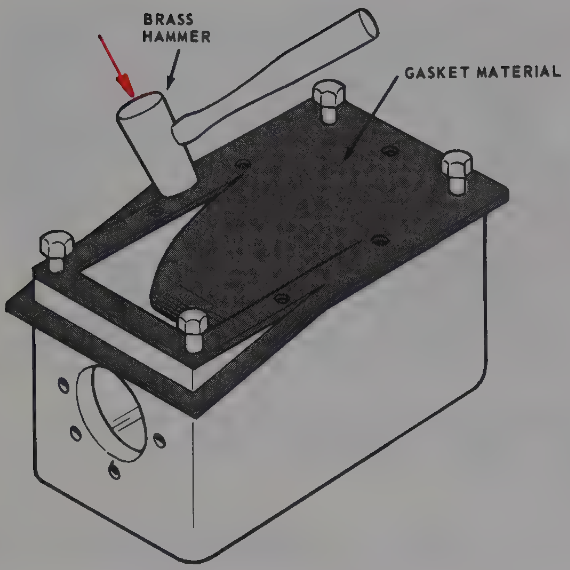


Fig. 4-13. Making a gasket. Four corner screws hold gasket material in place while tapping. A ball peen hammer is used for holes.

always true. Corners can present problems. Torque loss can reduce pressure on the gasket surface. Gaskets may shrink slightly and minute part shifting can break the seal. For these reasons, it is generally considered good practice to use a sealant on MOST gaskets.

The addition of a sealant helps hold the gaskets in place during assembly. Also, small cracks, indentations, and corner voids are sealed. In short, the use of a good sealant provides additional assurance that the joint will be leakproof.

REMEMBER: A small amount of oil seepage will, due to engine heat, spread over a large area. This produces a messy looking job and is certain to deposit oil dribbles on the customer's garage floor - hardly a good advertisement for any shop.

SEALANT

Gasket sealer or sealant is a liquid or semiliquid material that is sprayed, brushed, or spread on the gasket surface. Various types, having different properties, are available. Some set up hard and others remain pliable. Most, but not all, are highly resistant to oil, water, gas, grease, antifreeze, mild acid, and salt solutions. Resistance to heat and cold vary, but in general, most sealers are adequate in this respect for all uses other than exhaust applications.

The mechanic should be thoroughly familiar with sealers and their properties and uses. The chart in Fig. 4-14 lists various sealants, properties, and recommended uses for various products. Sealant manufacturers will be happy to provide the mechanic with specific recommendations for using their products.

The use of too much sealer is generally worse than using none at all. Excess sealer is squeezed out of the joint and can clog water, gas, and oil passages. A THIN coat is ample. On some oil pan gaskets with corners difficult to seal, a small dab where the gaskets meet is permissible.

In general, a nonhardening, flexible sealer will produce the desired results.

Some parts with extremely small holes or ports, such as carburetors and automatic transmission valve bodies, can be rendered useless if ANY sealant is squeezed into the openings. In cases such as this, do not use a sealant.

In any specific application, be sure to follow the manufacturer's recommendations.

USING RUBBER GASKETS

Rubber gaskets are highly resilient and will usually do a good job of sealing without the addition of a sealer. In fact, rubber gaskets tend to extrude (squeeze out) under pressure when a sealer is used. Unless a sealant is specifically recommended, a rubber gasket should be installed WITHOUT SEALER.

HOLDING GASKET DURING ASSEMBLY

Where a sealant is used, the gasket will usually stay in place during assembly.

If sealant is not being used and the gasket tends to slip, the gasket can be held in place with a thin coat of grease or quick-drying contact adhesive. On rubber gaskets, the use of grease or sealant is not recommended.

Some parts, such as oil pans, can be difficult to assemble without disturbing gasket position. In some cases, in addition to using a sealant, it is advisable to tie the gasket with thin soft string. The parts may be tightened with the string in place. Patented gasket holders are also available and work well.

In other instances, such as cylinder head installation, guide pins are used to hold the gasket in alignment.

Make certain the gasket is correctly installed and that it remains in alignment during assembly. See Fig. 4-15.

USE PROPER SEQUENCE AND TORQUE WRENCH

After running all fasteners up snug, tighten them in the proper sequence as recommended in the chapter on fasteners. First, tighten to one-third torque, second to two-thirds torque, third to full torque.

Improper sequence and torque, in addition to snapping fasteners and parts, producing distortion, will very likely cause the gasket to fail to seal. Excessive torque can place the gasket under too much pressure. This can cause it to extrude badly. Fig. 4-16 shows the results of improper tightening procedures as related to gasket sealing.

PRODUCT	TYPE OF APPLICATION	TEMP. RANGE (DEGREES F.) AND PRESSURE RANGE	USES	RESISTS	DRYS SETS SOLVENT
Form-A-Gasket® No. 1	Spreader Cap. spatula or mechanical spreader.	−65 to 400 5000 psi	Permanent assemblies, repair gaskets, fittings, uneven surfaces, thread connections, cracked batteries.	Water, steam, kerosene, gasoline, oil, grease, mild acid, alkali and salt solutions, aliphatic hydrocarbons, antifreeze mixtures.	Fast Hard Alcohol
Form-A-Gasket® No. 2	Spreader Cap. spatula or mechanical spreader.	−65 to 400 5000 psi	Semi-permanent reassembly work. Cover plates, threaded and hose connections.	Water, steam, kerosene, gasoline, oil, grease, mild acid, alkali and salt solutions, aliphatic hydrocarbons, antifreeze mixtures.	Slow Flexible Alcohol
Aviation Form-A-Gasket® No. 3	Brush or Gun	−65 to 400 5000 psi	Sealing of close fitting parts. Easy to apply on irregular surfaces.	Water, steam, kerosene, gasoline, oil, grease, mild acid, alkali or salt solutions, aliphatic hydrocarbons, antifreeze mixtures.	Slow Flexible Alcohol
Indian Head Gasket Shellac	Brush	−65 to 350 Variable	General assembly work and on gaskets of paper, felt, cardboard, rubber, and metal.	Gasoline, kerosene, greases, oils, water, antifreeze mixtures.	Slow Hard Alcohol
Pipe Joint Compound No. 51	Brushable, viscous liquid	−65 to 400 5000 psi	Threaded fittings, flanges. Can be applied over oil and grease film.	Hot and cold water, steam, illuminating gas, fuel oils, kerosene, lubricating oils, petroleum base hydraulic fluids, antifreeze mixtures.	Slow Flexible Alcohol
Super '300' Form-A-Gasket®	Brush or Gun	−65 to 425 5000 psi	Assembly work on hi-compression engines, diesel heads, cover plates, hi-speed turbine superchargers, automatic transmissions, gaskets.	Hi-detergent oils and lubricants, jet fuels, heat transfer oils, glycols 100%, mild salt solutions, water, steam, aliphatic hydrocarbons, diester, lubricants, antifreeze mixtures, petroleum base hydraulic fluids, aviation fuels.	Slow Flexible Alcohol
Stick-N-Seal®	Brush or Gun	−40 to 200 as an adhesive to 400°as a sealant Variable	Seal rubber to rubber, rubber to metal, sealing hydraulic and transmission oils, cork to metal.	Gasoline, grease, oils, aliphatic, hydrocarbons, antifreeze mixtures. Glycols, alcohols.	Fast Flexible Methyl Ethyl Ketone and Toulene
Anti-Seize Compound	Stiff Brush or Spatula	−60 to 1000 —	Threaded connections, cable lubrication, manifolds, nuts and bolts, sliding metal surfaces especially where dissimilar metals meet. Prevents galling and seizure. Excellent on stainless steel.	Water, steam. Primarily designed as antibinding and anti-corrosion compound.	— Flexible Kerosene and light lubricating oil
Silicone Form-A-Gasket Blue	Tube Cartridge Syringe	−80 to 600 5000 psi	Oil pan, valve covers, timing covers, oil pumps, transmission pans.	Regular and synthetic oil, antifreeze, grease, and transmission fluid.	Fast Flexible Gasket remover
Silicone Form-A-Gasket Red	Tube Syringe	−80 to 650 5000 psi	Cross over manifolds, exhaust manifolds, hi-temp cam covers, hi-temp timing covers.	Regular and synthetic oil, antifreeze, grease, and transmission fluid.	Fast Flexible Gasket remover
Silicone Form-A-Gasket Black	Syringe	−80 to 600 5000 psi	Water pumps, thermostat housings.	Regular and synthetic oil, antifreeze, grease, and transmission fluid.	Fast Flexible Gasket remover
Loctite Master Gasket Flange Sealant	Syringe	−65 to 300 1900 psi	Overhead cam housings, cast metal timing and differential covers, compressors, and transmission assemblies.	Gasoline, gasohol, diesel fuel, regular and synthetic oils, grease, and transmission fluid.	Fast Flexible Gasket remover
Loctite Quick Metal	Tube	Up to 300 3000 psi shear strength	Restores flywheel to pilot bearing fit. Restores wheel spindle to wheel bearing fit, etc.	Resistant to oils, cutting fluids, chlorinated solvents.	Fast Hard None (when set)
Loctite Lock N' Seal	Tube Bottle	40 to 300	Starter and alternator mounts, flywheel and gear spline keys. Body and frame bolts. Vibration-prone assemblies. Protects threads from corrosion.	Oils, greases, fuels.	Fast Medium Solvent
Loctite Super Bonder	Tube Bottle	Up to 175 5000 psi	General purpose. Bonds metals, alloys, plastics, vinyls, rubber, glass, etc.	Cold, mild vibration.	Fast Hard Super glue type remover
Weatherstrip Adhesive	Tube	Up to 175	Door and windshield weatherstripping.	Freezing and high temperatures.	Fast Tough Solvent

Fig. 4-14. Sealant and adhesive chart. (Permatex)

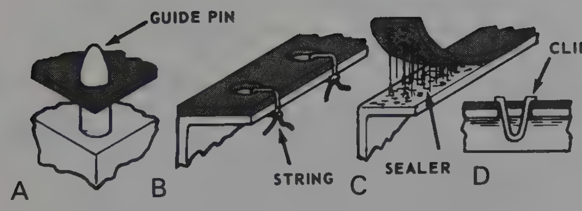


Fig. 4-15. Holding gasket in place. It is important that gaskets be held in alignment during assembly.

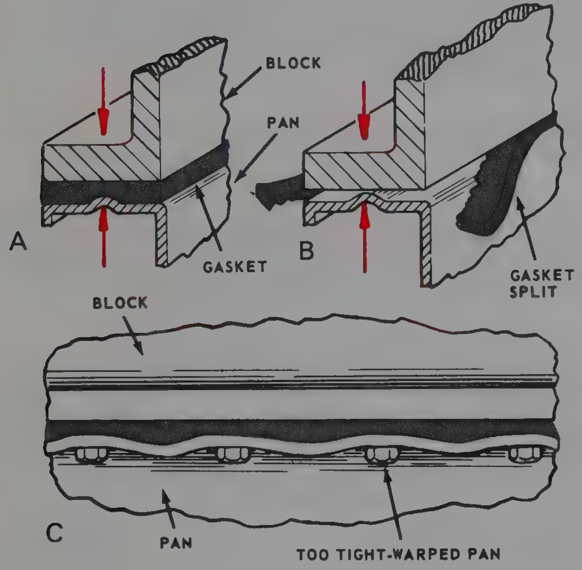


Fig. 4-16. Overtightening will cause damage. A—Proper fastener tension. B—Excessive tightening has split cork pan gasket. C—Excessive tension has warped oil pan flange.

STAMPED PARTS REQUIRE EXTRA CARE

Relatively thin stamped parts such as rocker arm covers, oil pans, and some timing covers, if bent along the engaging edge, must be straightened before installation. Place the part edge on a smooth, solid metal surface. Gently tap to straighten the bent sections. When installing, do not overtighten as the parts will be bent again, Fig. 4-17.

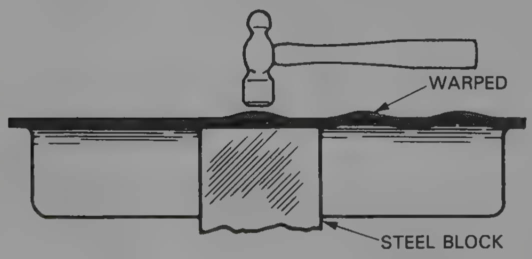


Fig. 4-17. Straighten warped flange. Warped edges cause leaks. Straighten them before installation.

REMEMBER THESE STEPS IN PROPER GASKET INSTALLATION

1. Clean parts, fasteners, and threaded holes.
2. Remove any burrs, bent edges, or excessive warpage and check for dents and scratches.
3. Select a new gasket of the correct size and type.
4. Check the gasket for fit.
5. Where sealant is used, apply a THIN coat of the correct sealant on one side of the gasket. Place the gasket with the coated side against the part. Spread a THIN coat on the uncoated side. Do not slop sealant into parts. Wipe off excess.
6. If alignment difficulty is anticipated during assembly, secure the gasket by additional means.
7. Carefully place mating part in place.
8. Coat threads of fasteners with anti-seize (unless prohibited). Install in their PROPER location and run up snug.
9. Torque fasteners in proper sequence.
10. If necessary, retorque after a specified length of time. (These instances will be covered in later chapters.)

ANALYZE GASKET FAILURE

When a gasket fails in service, there has to be a reason for the failure. If you do not detect the reason, your own installation might fail also. The following simple steps will help you find the underlying cause of the failure:

1. Ask the owner about any unusual conditions. Try to determine if the gasket failed suddenly or over a period of time.
2. Before disassembly, check fastener torque with a torque wrench. You can loosen each one and notice the reading at break-away. This will be somewhat less than true torque. Another method is to carefully mark the position of the head of the screw or nut in relationship to the part (use a sharp scribe). Back the nut off about one-quarter turn. Carefully retighten until the scribed lines are exactly in alignment. If done properly, this will give you a fair indication of torque at the time of failure.

   If the torque is significantly below that specified, this could well be the cause of failure. If torque varies from fastener to fastener, this too could be the cause.

   ALWAYS ALLOW AN ENGINE TO COOL BEFORE REMOVAL OF A CYLINDER HEAD. A cylinder head can be warped by removing it when too hot.
3. Following disassembly, carefully blot off any grease, oil, dirt, and carbon from the gasket. Do not rub or wash the gasket immediately, as this may remove tell-tale signs. Inspect the gasket for signs

of uneven pressure, burning, corrosion, cracks, or voids. Check to determine if the gasket is of the correct material and type for the job.

4. Inspect the mating parts for warpage and burrs. ALWAYS TRY TO FIND THE CAUSE OF GASKET FAILURE SO YOU MAY EFFECT A CORRECTION WHEN INSTALLING A NEW GASKET.

RETORQUE

Constant fastener tension and the expansion and contraction of parts will tend to further compress a gasket. This will leave the fasteners below proper torque. In a critical application, such as a head gasket, it can cause gasket failure unless the fasteners are retorqued after a period of time. Situations requiring retorque will be discussed in later chapters.

OIL SEALS

An oil seal can be used to confine fluids, prevent the entry of foreign materials, and separate two different fluids.

An oil seal is secured to one part while the sealing lip allows the other part to rotate or reciprocate (move).

Oil seals are used throughout the mechanical parts of the car. Engine, transmission, drive line, differential, wheels, steering, brakes, and accessories all use seals in their construction.

OIL SEAL CONSTRUCTION AND MATERIALS

Seals are made up of three basic parts. A metal container or case, the sealing element, and a small spiral spring called the GARTER spring.

Sealing elements are usually made of synthetic rubber or leather. Synthetic rubber seals are displacing leather in most applications. The rubber seal can be made to close tolerances and can be given special configurations (shapes). Also, specific wear and heat resistant properties can be imparted.

In the rubber oil seal, the sealing element is bonded to the case. The element rubs against the shaft. The case holds it in place and in alignment. The garter spring forces the seal lip to conform to minor shaft runout (wobble) while at the same time maintaining constant and controlled pressure on the lip. Fig. 4-18 illustrates typical oil seal construction.

VARIOUS DESIGNS ARE USED

Many different element and lip shapes are provided. Each is designed to provide the best seal for a specific task. Fig. 4-19 shows several designs. Notice that more than one lip can be used. The outside diameter, or one edge, may be coated with rubber to provide better OD (outside diameter) sealing.

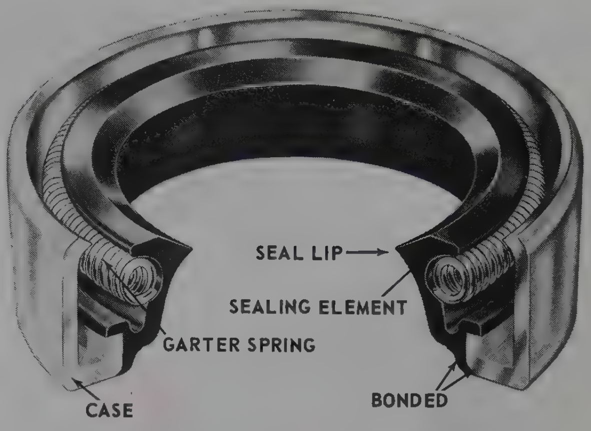


Fig. 4-18. Typical oil seal construction. (Victor)

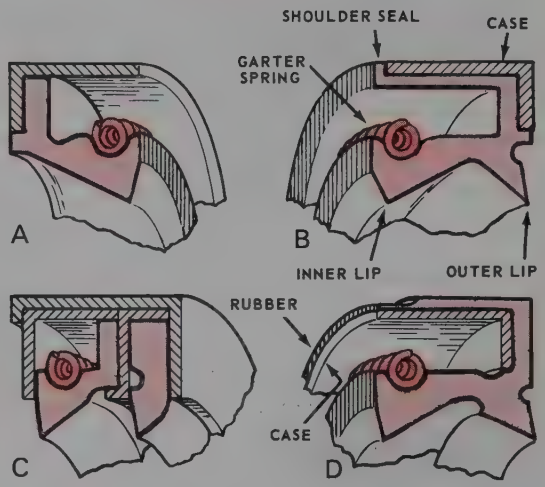


Fig. 4-19. Oil seal designs. A—Single lip. B—Double lip with rubber shoulder seal. Inner lip controls oil and outer lip keeps out dust and water. C—Double lip. Both lips control oil. D—Double lip with rubber outer coat to assist outside diameter sealing.

OTHER TYPES OF OIL AND GREASE SEALS

Engine rear main bearing oil seals are usually constructed in two halves. They may be made of graphite impregnated asbestos wicking or synthetic rubber. Some grease (not oil) seals use a felt sealing element. Occasionally, a combination will use an inner rubber seal and a felt outer seal, Fig. 4-20.

OIL SEAL REMOVAL

Seals may be removed by prying, driving, or pulling, depending on the location.

Before removal, notice the depth to which the seal was installed. As with a gasket, inspect the seal after

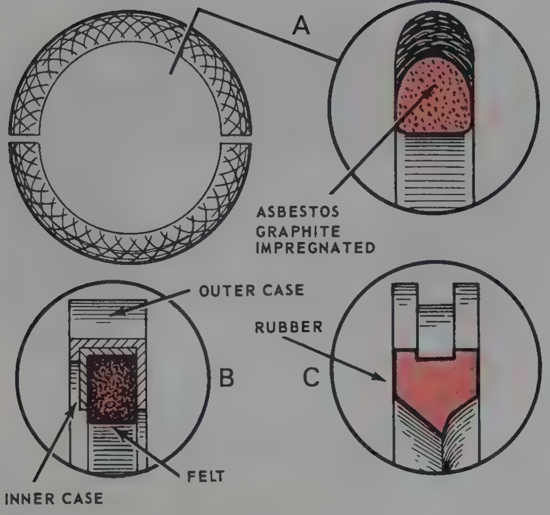


Fig. 4-20. Other seal types. A—Main bearing (rear) seal made of asbestos wicking. Both upper and lower halves fit into grooves in block and cap. B—Typical grease seal using a felt sealing ring. C—Synthetic rubber main bearing oil seal. Rubber O-rings (not shown) are used in several areas. They are simple round rubber rings.

removal for any signs of unusual wear or hardening. DO NOT REUSE SEALS. WHEN UNITS ARE DOWN FOR SERVICE, REPLACE THE SEALS. Use care to avoid damage to seal bore during seal removal. Such damage can cause leaks, difficult installation, and damage to new seal. See Fig. 4-21.

SEAL INSTALLATION

After removing the old seal, carefully clean the seal recess or counterbore. Inspect for nicks or burrs. Compare the old seal with the new one to make certain you have the proper replacement. The OD must be the same. The ID (inside diameter) may be slightly smaller in the new seal as it has not been spread and worn. The width can vary a little.

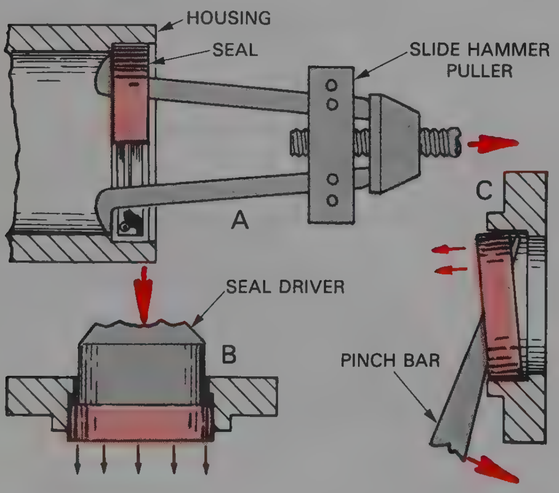


Fig. 4-21. Seal removal. A—Slide hammer puller jaws are pushed through seal and then expanded. Operating slide hammer will pull seal out. B—A seal driver can often be used. C—Many seals can be "popped out" with a small pinch bar. When a seal must be removed, while a shaft is present, a hollow threaded cone is threaded into seal. The cone, attached to a slide hammer, will withdraw seal.

COAT WITH NONHARDENING SEALER

If necessary, coat inside of the seal counterbore with a THIN coat of nonhardening sealer. If there is too much sealer, the seal may scrape it off as it enters, causing the surplus to drip down on the shaft and sealing lip. This can cause seal failure, Fig. 4-22.

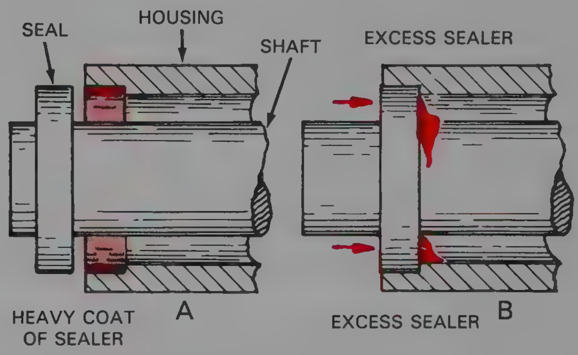


Fig. 4-22. Apply sealer sparingly! A—Seal counterbore has been given a heavy coat of sealer. B—When the seal is driven into the counterbore, excess sealer will be forced out onto shaft and seal lips. In addition to ruining seal, this could clog some opening in mechanism.

DRIVING THE SEAL WITH NO SHAFT PRESENT

After preparing the seal counterbore, place the seal squarely against the opening WITH THE SEAL LIP FACING INWARD OR TOWARD THE AREA IN WHICH THE FLUID IS BEING CONFINED. If the lip faces the other way, it will probably leak, Fig. 4-23.

USE SUITABLE DRIVER

The driver should be just a little smaller (about .020 in. or 0.51 mm) than the seal OD when the seal will be driven below the surface. If the seal is to be driven flush (even with surface), the driver can be somewhat wider. In any case, the driver should contact the seal near the outer edge only. NEVER STRIKE THE INNER PORTION OF A SEAL. This might bend the flange inward and distort the sealing element, Fig. 4-24.

If a seal driving set is not available, a section of pipe of the correct diameter can be used. Make sure the ends are square. If a hammer is used to start seal, follow it up with a drift punch. Be careful to strike at different spots (near the outer edge) each time. If the seal begins to tip, strike the high side. REMEMBER: A SEAL IS

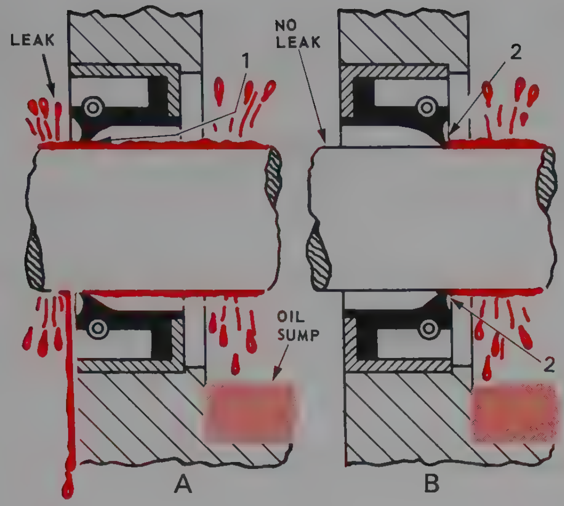


Fig. 4-23. Seal lip must face fluid! A—Seal has been installed backwards. Lip faces away from fluid causing fluid 1 to force seal lip from shaft, causing leakage. B—Seal is correctly installed with lip facing fluid. Pressure at 2 forces seal against shaft, preventing a leak.

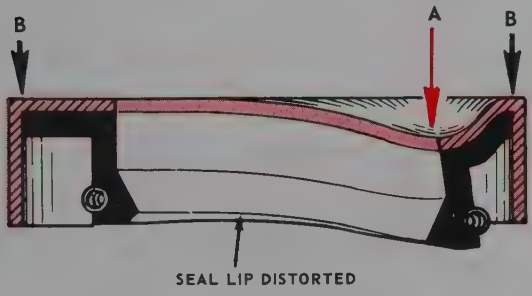


Fig. 4-24. Damaged seal. Seal case badly distorted by careless installation. Punch struck case at A. All driving force should be applied at B. This seal would leak badly.

EASILY DAMAGED THROUGH IMPROPER INSTALLATION—BE CAREFUL!

DRIVE SEAL TO PROPER DEPTH

If a locating shoulder is used, drive the seal snugly against it. This is especially important if the seal inner edge has a rubber sealing compound designed to flatten against the shoulder. See B, Fig. 4-19.

When no shoulder is used, keep the seal square and stop at the specified depth. If you drive it in too far, you may ruin it while attempting to pull it back.

WHEN SEAL LIP MUST SLIDE OVER SHAFT DURING INSTALLATION

When driving a seal that must slip over a shaft, use care to see that the sealing lip is not nicked or abraded.

If a plain shaft (no keyway, splines, or holes) is involved, check the shaft carefully for burrs and nicks. If any are found, remove them by polishing (shoe shine motion) with CROCUS cloth (a very fine abrasive). Examine the shaft surface where the sealing lips will operate. It must be smooth at this point.

If the end of the shaft is chamfered (beveled), polish the chamfered area. If the chamfer is too steep (30 deg. about maximum), either reduce it or use a mounting bullet or thimble. See Fig. 4-25.

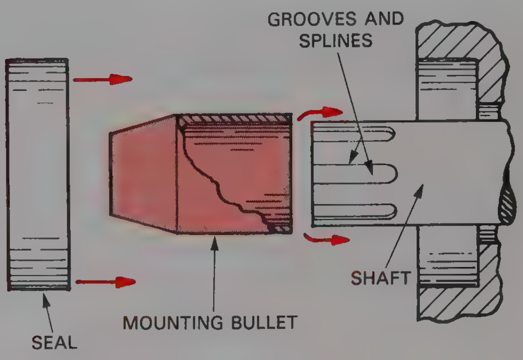


Fig. 4-25. Installing seal using mounting bullet. Bullet or sleeve is placed over shaft and seal can then be installed without lip damage by spline edges.

Once the shaft is chamfered and free of scratches, wipe it CLEAN and apply a film of oil to the full length. Place a small amount of oil or soft grease on the seal lip and inner face. With the seal lip facing toward the fluid to be confined (counterbore with a thin coat of sealer), carefully slip the sealing lips over the chamfer onto the shaft. Slide the seal along the shaft until it engages the counterbore. Using a suitable driver, seat the seal, Fig. 4-26.

MOUNTING SLEEVES AND BULLETS

When driving a seal that must first slide over a keyway, drilled hole, splines, or shaft square end, a mounting sleeve or bullet should ALWAYS be used. This will prevent damage to the seal lip. Fig. 4-25

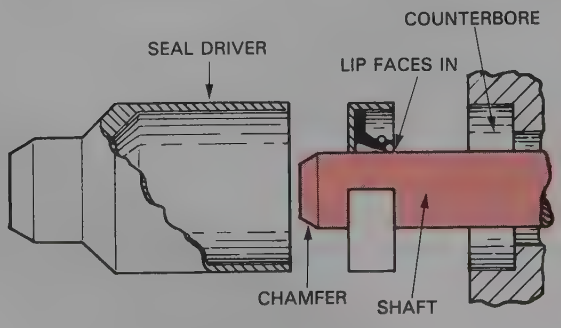


Fig. 4-26. Installing a seal over a plain shaft. Seal will start over chamfered shaft end without damage. Shaft must be smooth, clean, and oiled.

illustrates the proper setup. The OD of the mounting sleeve should not be much over 1/32 in. (0.79 mm) larger than the shaft or the seal lips will be spread excessively.

In the event no mounting tools are available, one may be quickly made by using shim stock (thin brass sheets in various thicknesses).

Wrap the stock tightly around the shaft (one wrap with a small lap) and trim off. Tin the lap with a soldering iron. File the lapped edge after soldering. Then, smooth with abrasive cloth. Bend the leading edge inward and it is ready to use, Fig. 4-27.

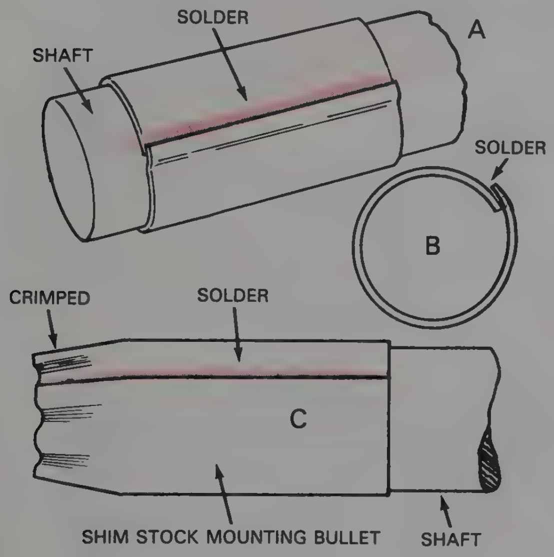


Fig. 4-27. Shim stock mounting sleeve. A—Sleeve formed and soldered. B—Edge sanded smooth. C—Sleeve installed and leading edge crimped. All edges must be smooth.

REMEMBER THESE STEPS IN SEAL INSTALLATION

1. Clean seal counterbore, remove nicks and burrs, and, if necessary, coat with a VERY THIN layer of non-hardening sealer.
2. Inspect shaft, polish burrs and scratches with CROCUS cloth. Pay particular attention to the area where the seal lip will operate.
3. Check the new seal for correct size and type.
4. Lube the sealing element and shaft.
5. If needed, install mounting tool on shaft.
6. Push seal, LIP EDGE TOWARD FLUID, up to counterbore.
7. Using a suitable driver, seat the seal. Make certain it is in the proper depth and is square with the bore.

IMPORTANT!

The seal must be a drive or press fit in the counterbore. A seal that slides in easily will leak.

When the housing has air vents to relieve pressure build up, make sure they are open. If clogged, pressure within the housing will force the lubricant past the best of seals.

If the shaft is installed after the seal, observe the same precautions against seal damage.

Cleanliness here, as in all automotive service, is important.

If a new seal is improperly installed and must be removed, throw it away. Use another new seal.

Further specific instructions regarding gaskets, sealants, and seals will be given in chapters to which they apply.

O-RING SEALS—CONSTRUCTION

O-ring seals are generally solid, round (doughnut shaped), and made from an elastomer (synthetic rubber or plastic). They are used to create a seal between two parts, close off passageways, prevent the loss or transfer of fluids, and help retard the entry of dust and water. See Fig. 4-28.

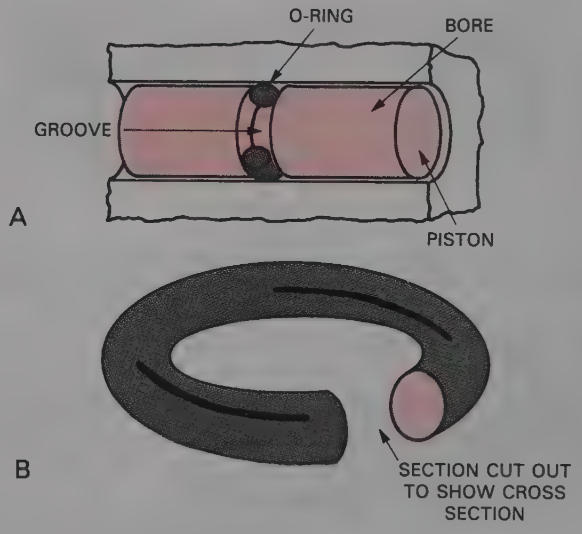


Fig. 4-28. O-rings. A—Note how O-ring is fitted into groove in piston. This allows piston movement while maintaining a seal. B—Typical O-ring construction. (Parker Seal)

O-RING OPERATION

Because the O-ring is composed of a somewhat soft, pliable material, it seals when slightly squeezed between two surfaces. If the O-ring is also sealing under pressure, the pressure itself will aid in deformation (causing it to deform) of the ring, further making a final seal. They can be used to seal both static (nonmoving) and dynamic (moving) parts. Fig. 4-29, A, shows an O-ring

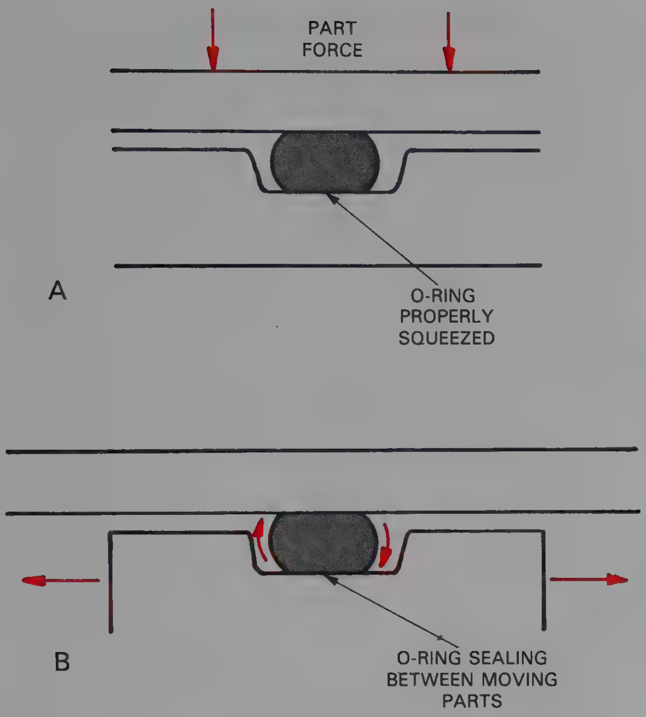

PART FORCE
A
O-RING PROPERLY SQUEEZED
B
O-RING SEALING BETWEEN MOVING PARTS

Fig. 4-29. When an O-ring is installed, it is slightly squeezed. Note oblong shape. The O-ring attempts to return to its round shape and thus maintains constant pressure to form a leakproof seal. A—Static seal. B—Dynamic seal. (Deere & Co.)

correctly installed in a static application. Fig. 4-29, B, illustrates an O-ring sealing between moving parts.

O-RING INSTALLATION STEPS

1. Make sure the new O-ring is the correct size and that it is compatible with the fluid being sealed.
2. Clean the area where the O-ring is to be installed thoroughly.
3. Inspect the O-ring grooves or notches for burrs or nicks which could damage the new ring. Dress any sharp areas with a fine abrasive stone. Again, thoroughly clean the area to remove any metal and stone particles.
4. Check the shaft or spool (if used) for sharp edges or nicks. Remove any damaged spots with a fine abrasive stone or cloth. Reclean the area thoroughly.
5. Before installation, lubricate the O-ring with the same type of fluid used in the part or system.
6. Install the O-ring. Protect it from sharp edges and other parts. Do not stretch it more than necessary.
7. Be sure the parts are correctly aligned before mating to avoid damage to the O-ring.
8. Make a final check after the O-ring is installed to be sure there are no leaks and that the parts move correctly.

O-RING FAILURE DIAGNOSIS

Improper handling, installation, and application will reduce O-ring service life. Fig. 4-30 illustrates some common O-ring failures. Be sure to follow manufacturer's recommendations when replacing or working with O-rings. When replacing O-rings that have failed in service, try to diagnose the reason behind the failure. Fig. 4-30 shows several common causes.

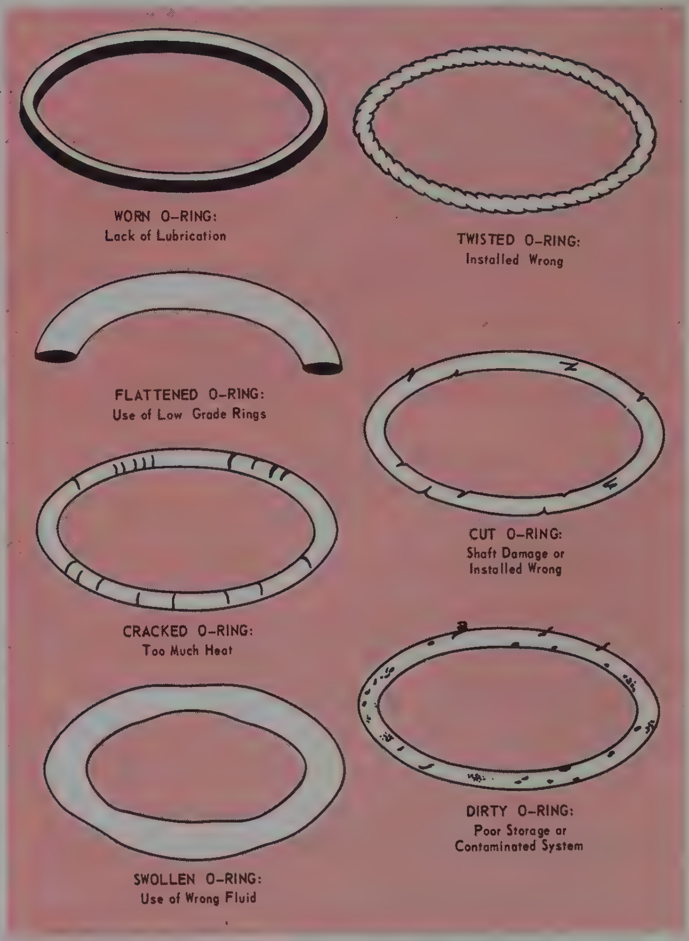

WORN O-RING: Lack of Lubrication
TWISTED O-RING: Installed Wrong
FLATTENED O-RING: Use of Low Grade Rings
CUT O-RING: Shaft Damage or Installed Wrong
CRACKED O-RING: Too Much Heat
DIRTY O-RING: Poor Storage or Contaminated System
SWOLLEN O-RING: Use of Wrong Fluid

Fig. 4-30. Some typical causes of O-ring failure. (Deere & Co.)

ADHESIVES

The modern automobile uses many types of adhesives to secure a varied array of parts. The adhesive material is generally a liquid or semiliquid substance. It can be spread on (with its own dispenser or other suitable tool), brushed on, or sprayed on.

Most adhesives, when dry, form a hard bond. Others remain somewhat pliable (rubbery). They can be removed with special removers or thinners.

Adhesive uses include: securing weatherstripping, underhood fiberglass pads, body side molding, and inside rear view mirror bases (glued to the windshield).

Follow manufacturer's recommendations when using a specific adhesive.

SUMMARY

Gaskets and seals are used throughout the car. Their selection, preparation, and installation is of critical importance.

Gaskets provide leakproof joints. They are made of paper, cork, rubber, asbestos, steel, and copper. Different materials or combinations of materials are needed for specific applications.

Gaskets are of single layer and multiple-layer construction. Many use steel or copper outer layers with an asbestos center. The single layer, beaded steel head gasket is popular on high compression engines. Gaskets may have additional material around the sealing edges to increase unit loading at these points.

Gaskets, once used, should be discarded. Beware of kinked multiple-layer gaskets.

Where sealant use is recommended, use sparingly. Sealants of many kinds are available in both hardening and nonhardening types. Select the proper type for the job at hand.

When a gasket has failed, try to determine why, so you can correct the condition.

Oil seals are used to confine fluids, prevent the entry of foreign material, and often to separate two fluids.

Seals are generally constructed in three parts - steel case, sealing element, and garter spring. Some specialized seals use asbestos wicking or sections of synthetic rubber.

Seals use both leather and synthetic rubber sealing elements. Many different seal lip designs are used.

When installing seals, the shaft must be smooth, the counterbore lightly coated with nonhardening sealer, and the seal driven to the proper depth. The seal lip should face toward the fluid to be confined. Protect seal lip when installing by chamfering or using special mounting tools. Always use a suitable driver. Lubricate seal and shaft before installing the seal. Cleanliness must be observed at all times.

O-rings are solid, pliable round rings. They are used to seal between parts and stop the entry of dust and water. They seal best when slightly compressed. Be sure to carefully follow installation instructions so the O-ring will not be damaged. Use care when handling. Always follow manufacturer's recommendations when working with and replacing an O-ring. Never substitute or reuse O-rings.

The modern vehicle makes use of many different adhesives to secure parts. The adhesive material is usually a liquid or semiliquid.

Adhesives, when dry, can form a hard or pliable bond, depending upon the chemicals used. Follow manufacturer's recommendations when using or removing adhesives.

SUGGESTED ACTIVITIES

1. Determine how many separate gaskets are used on a V-8 engine. List the materials used in their construction.
2. Make a gasket by placing the gasket material over the part and tapping around the edges and holes.
3. Secure a head gasket that has BLOWN (failed). Examine it carefully and see if you can determine the cause. List some of the possible causes of head gasket failure.
4. With a torque wrench and following specifications, go over the fasteners on an engine that has been in service for some time. Were they torqued to specifications? If not, what had happened during service? What part could the gaskets have played in this torque change?
5. Check this same car for oil, gas, and water leaks. Do not overlook the transmission, rear end, and brake lines. Is the car free of leaks? If leaks are present, what could be the major cause?
6. Inspect some used oil seals and O-ring seals that have failed in service. What shape are they in? What had happened to them? Discount damage that may have been incurred during removal.

SO WHAT'S A LITTLE LEAK?

You might ask why a chapter is devoted to such "trifles" as gaskets and seals. It might seem that they are so simple that a passing mention would be enough. Surely they are not that important and if some part leaks, well - so what's a little leak!

The facts are that proper gasket and seal selection and installations are actually VERY IMPORTANT. Every repair job is made up of a series of steps or operations - some large and some small. All operations, including the little things, are very important.

Leaks are not only messy and create poor customer relations, they cause part failure and expensive comebacks, plus real damage to the reputation of both garage and mechanic. In fact, even a minor leak may cost someone's life!

Let's take the case of mechanic "X" (unfortunately, there are too many mechanics of this type). Assigned to a brake job, this service technician had replaced the master cylinder and rear wheel cylinders, repaired the front calipers, turned the rear drums and front discs, installed new brake shoes and pads, and replaced front wheel seals and rear axle seals.

Upon completion, the technician bled and adjusted the brakes, checked for fluid leaks, and after road testing declared the job complete. The customer, a sales representative, took delivery.

Several weeks later, the representative was returning home. The mountain road was dark. Its wet surface shimmered in the glare of the headlights. Rounding a curve, a rock slide loomed out of the night. The representative did not panic. The car's speed was not excessive, and though it would be touchy, there was time to stop.

Considering the slippery blacktop, the driver pressed hard on the brake pedal, but not too hard. The car began to slow, and then it happened. The left rear wheel grabbed, locked up tight, lost traction, and sent the car into a violent slide.

The driver released the brake pedal, cut the wheel, stopped the skid, and reapplied the brakes. Another lockup, another terrifying skid, but now it was too late. The car struck the corner of the rock slide with a sickening thud, bounced high in an arcing skid, and plunged off the highway.

The driver was lucky and lived through the crash. Subsequent study by a safety investigator disclosed that mechanic "X" had driven the left rear axle seal in so that it was cocked to one side. The axle lube had worked through and fouled the brake lining.

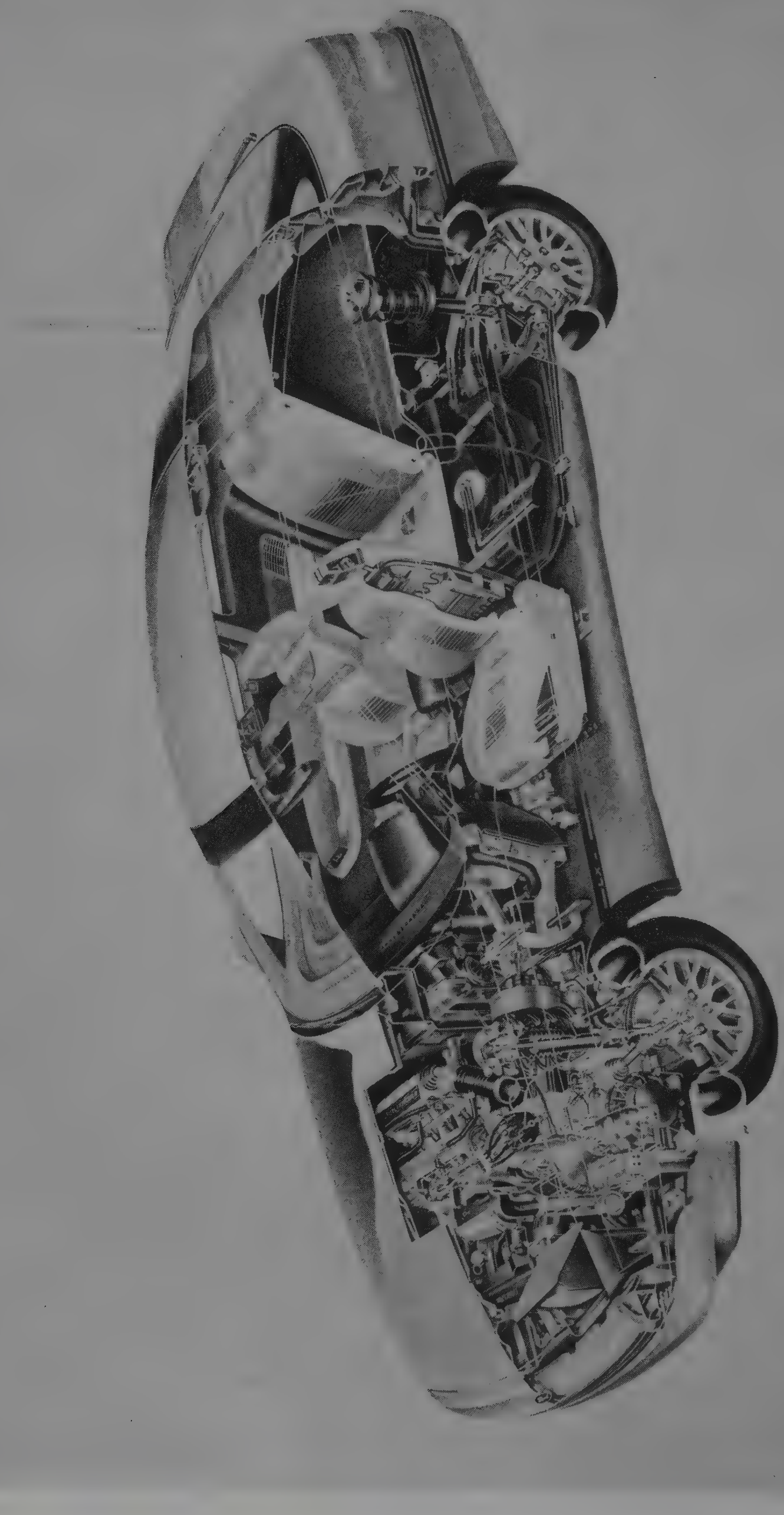
Being a mechanic takes intelligence, training, technical knowledge, skill, and attention to details. If you ever here someone say, "So what's a little leak," – YOU TELL THEM!

KNOW THESE TERMS

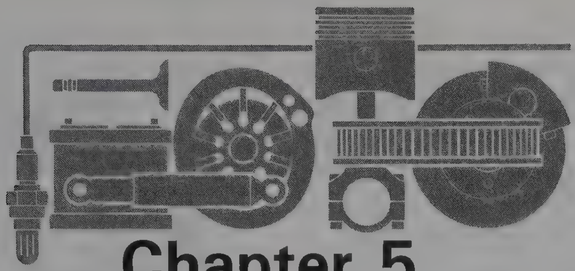
Gasket, Mating surface, Chamfering, Sealant, Antiseize, RTV, Oil seals.

QUIZ - Chapter 4

1. Define the word GASKET.
2. Give two important reasons for installing gaskets.
3. List seven materials that are used in gasket construction.
4. Name four factors that influence the service life of a gasket.
5. Gaskets are of either ____________ layer or ____________ layer construction.
6. A gasket that must resist great heat will often use ____________ in its construction.
7. Define the term UNIT LOADING.
8. The beaded steel head gasket is used on ____________ ____________ engines.
9. What features in gasket construction provide higher localized unit loading?
10. If you plan a complete engine repair job you would order an ____________ set.
11. Old gaskets generally can be reused with success. True or False?
12. Always clean and check both ____________ surfaces before installing a gasket.
13. A gasket that has shrunk can often be brought back to size by ____________ in ____________.
14. A sharp crease in a multiple-layer gasket, if it is straightened out, will not harm the gasket. True or False?
15. Of what value is a gasket sealer?
16. Sealers are of the ____________ or ____________ type.
17. When applying sealer, always use a liberal amount. True or False?
18. Sealer should ALWAYS BE USED. True or False?
19. Name three ways of holding a gasket in place during part assembly.
20. What effect will improper torque and sequence have on the gasket sealing properties?
21. Bent mating surfaces on steel stampings should be ____________ before ____________.
22. List seven important steps in proper gasket installation.
23. Why should the mechanic try to determine the reason for gasket failure?
24. The typical oil seal is made in ____________ parts.
25. These parts are the ____________ ____________, the ____________ ____________, and the ____________ ____________.
26. Leather sealing elements are more widely used than synthetic rubber. True or False?
27. Draw a cross section of a single lip oil seal.
28. All oil seals are of one piece construction. True or False?
29. Describe three methods of removing an oil seal.
30. Place a small quantity of nonhardening sealer on the lips of each seal before installing. True or False?
31. Oil seal lip should face the fluid to be confined. True or False?
32. Describe a suitable oil seal driver.
33. Nicks and scratches on a shaft should be removed by polishing with ____________ ____________.
34. How are seal lips protected when the seal must slide over a splined, keyed, or drilled shaft?
35. Give seven important steps in proper seal installation.
36. Once a part has been torqued, the pressure will always remain constant. True or False?
37. O-rings are usually made of an ____________.
38. O-rings can be used on parts that move or on parts that do not move. True or False?
39. List eight steps that should be followed when installing O-rings.
40. Some adhesives when dry, form a ____________ bond, while other remain somewhat ____________.
41. List three parts that can be attached to the vehicle with adhesives.



Phantom view of a front-wheel drive car. Many types of hose and tubing are used in today's automobile. Study Chapter 5 carefully. (Ford)



Chapter 5

TUBING AND HOSE

After studying this chapter, you will be able to:

☐ Identify different types of tubing, hose, and fittings.

☐ Select the correct type tubing, hose, or fitting for the job.

☐ Properly install new tubing and hose.

Tubing and hose are used in many parts of the car. Brake systems, fuel delivery, vacuum applications, air conditioning, transmission fluid cooling, engine cooling, heating, power steering, lubrication, instrumentation all utilize either tubing or hose. In some instances, both are used. Selecting, using, and working with tubing is a part of most repair jobs. It is imperative that the mechanic be thoroughly familiar with the different types, their application, and proper installation.

TUBING MATERIAL

Annealed (soft) copper, half-hard copper, steel, aluminum, plastic, and stainless steel are some of the materials used in the manufacturing of tubing. Although all of these are found in the automotive field, the most common types are steel and copper.

Copper is more easily bent than steel but is not as strong. Fig. 5-1 shows the pressure various kinds of 3/16 in. (4.76 mm) OD (outside diameter) tubing with a wall thickness of around .020 in. (0.51 mm) will withstand. These are safe working pressures when a safety factor of five to one (material five times stronger than anticipated working pressure) is desired.

MATERIAL	O.D.	WALL THICKNESS	PRESSURE PSI
Polyethylene*	1/4 in.	.062	200
Nylon*	3/16 in.	.023	300
35 Aluminum		.018	500
5250 Aluminum		.018	1,000
Annealed Copper		.020	1,000
Half-hard Copper		.020	2,000
Double Wrap, Brazed Steel		.020	2,000
1010 Steel		.020	2,000
Annealed Stainless Steel		.020	3,000
4130 Steel		.018	5,000

* = at 70 deg. F.

Fig. 5-1. Pressure chart. Note variation in safe working pressure for various materials.

After studying Fig. 5-1, it becomes obvious the mechanic MUST KNOW what material is used in the tubing. The mechanic must also have accurate knowledge of the pressures and temperatures produce in the system on which the tubing will be used. Keep in mind that both the power steering and braking systems can develop pressure in excess of 1000 psi (6 895 kPa).

COPPER TUBING

Copper tubing is rustproof, easy to bend, and forms good joints. It can be used for gas lines, vacuum lines, lubrication lines, and for other low pressure applications. Copper is subject to work hardening (material becoming hard and brittle from bending). Therefore, it should be protected from excessive vibration. NEVER USE COPPER TUBING FOR BRAKE OR POWER STEERING WORK!

STEEL TUBING

When properly coated to prevent rust, steel tubing is suitable for almost all automotive applications. When used for high pressure systems such as brakes, the steel tubing should be of the double wrapped, brazed, and tin-plated type. The double wall construction gives good strength and makes the tubing easy to bend. The tinplating protects it from corrosion.

PLASTIC TUBING

Polyethylene and nylon are two of the materials used in the construction of plastic tubing. Soft plastic tubing has the advantage of flexibility, resistance to corrosion, and work hardening. It will not, however, stand high pressures and excess heat. It can be used for fuel, vacuum and some lubrication lines. Special inserts are needed to attach the soft plastic to conventional tube fittings.

HANDLING TUBING

When removing tubing from a roll, place the roll on a clean bench in an upright position. Hold the free end of the tube with one hand while rotating the roll over the bench with the other. Never lay the roll flat and pull the tubing upward as it will be twisted, Fig. 5-2.

Avoid working (bending) the tubing more than necessary. Store tubing where no heavy tools or parts are liable to cause dents. Keep the open end taped to prevent the entry of foreign material.

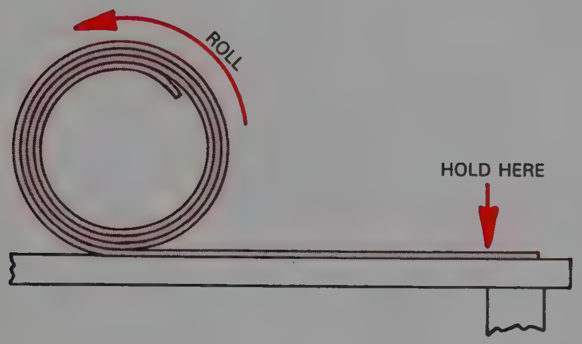


Fig. 5-2. Proper method of removing tubing from roll.

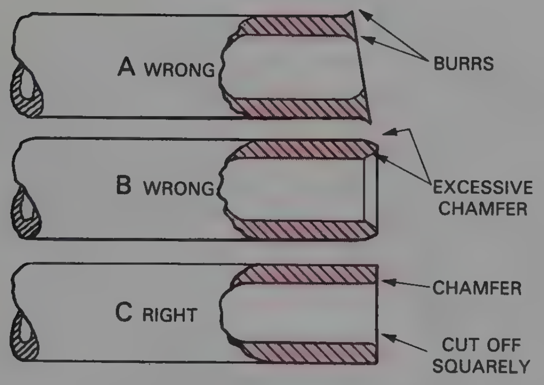


Fig. 5-3. A—Tubing cut at an angle and heavily burred. B—Cut squarely but reamed excessively. C—Cut squarely and reamed properly.

CUTTING TUBING

Tubing, especially when the ends are to be flared, must be cut off SQUARELY. Any burrs, either on the outside or inside, must be removed, Fig. 5-3.

Although a fine-tooth hacksaw will cut tubing, a faster and better method is to use a tube cutter. See Fig. 5-4.

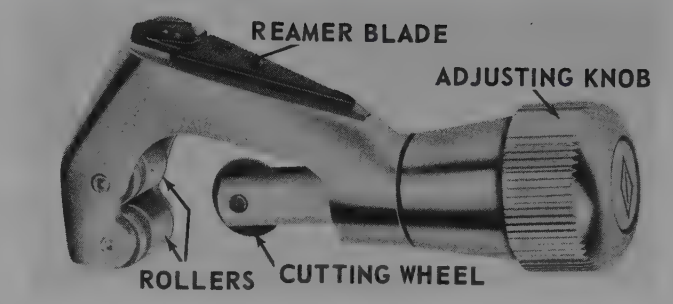


Fig. 5-4. Tube cutter. Note reamer blade in closed position. (Imperial Mfg. Co.)

The cutter is placed around the tube. The cutter wheel is brought into firm contact. Then, the cutter is revolved around the tubing. After each complete revolution, the cutter wheel is tightened. DO NOT OVERTIGHTEN! Repeat this process until the tubing is cut off, Fig. 5-5.

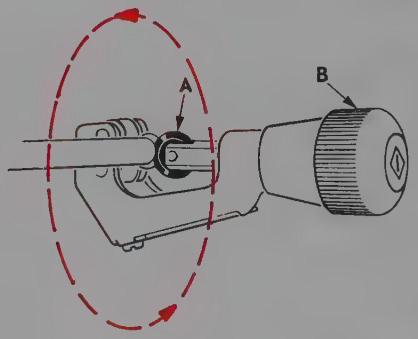


Fig. 5-5. Tighten cutter wheel A by turning handle B.

REMOVE BURRS

After cutting, you will probably notice a burred edge, especially on the inside. Remove the burr by using the reamer blade on the cutter tool. Ream only long enough to remove the burr. Excessive reaming will ruin the end for flaring, B, Fig. 5-3. When reaming, HOLD THE END OF THE TUBING DOWNWARD SO THAT THE CHIPS WILL FALL FREE. See Fig. 5-6.

TUBING CONNECTIONS

There are three basic types of tube connections: the FLARE, the COMPRESSION, and the PIPE. All have variations in design and are commonly used.

FLARE TYPE CONNECTION

In the flare connection, the end of the tubing is spread (flared) outward at an angle. The tube fitting securely grasps both sides of the flare to produce a

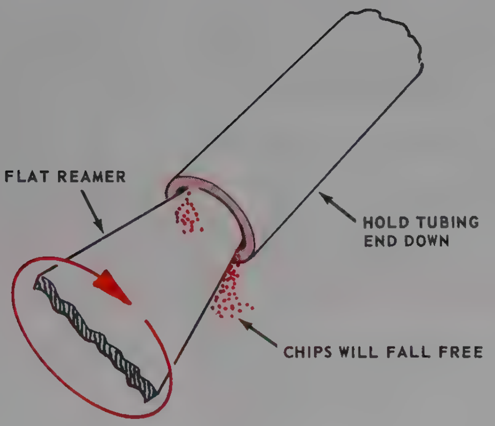

FLAT REAMER
HOLD TUBING END DOWN
CHIPS WILL FALL FREE

Fig. 5-6. Removing burrs with a reamer.

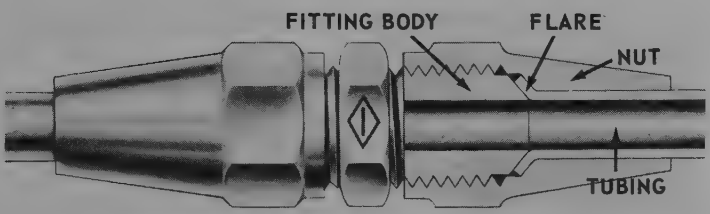

FITTING BODY
FLARE
NUT
TUBING

Fig. 5-7. SAE 45 deg. flare connection. Notice how flare is pinched between fitting body and nut.

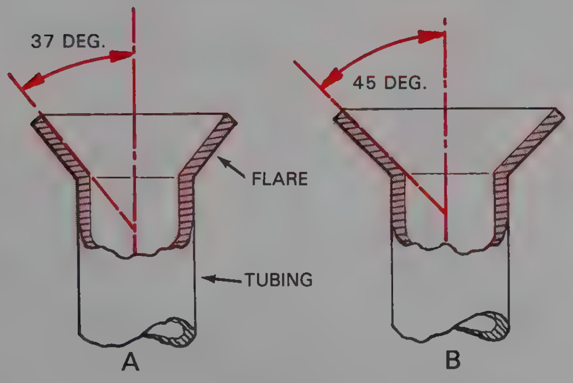

37 DEG.
45 DEG.
FLARE
TUBING
A
B

Fig. 5-8. Two flare angles. A—J.I.C. 37 deg. B—SAE 45 deg.

leakproof joint. Fig. 5-7 illustrates one type of flare connection.

FLARE ANGLES

There are two flare angles: 37 and 45 degrees. Be certain you determine the one needed. Look at Fig. 5-8.

FLARE TYPE

The flare may be a SINGLE-LAP, DOUBLE-LAP, or I.S.O. (International Standards Organization) type. WHEN FLARING DOUBLE-WRAPPED, BRAZED STEEL TUBING, ALWAYS USE A DOUBLE-LAP OR I.S.O. FLARE. This type of tubing, if a single-lap is used, will SPLIT! See Figs. 5-9, 5-10, and 5-66.

FLARE MUST BE ACCURATELY FORMED

The flare must be smooth and square with the centerline of the tubing. Careless cutting or improper use of the flaring tool will produce weak and uneven flares. These will always LEAK! When a flare is made incorrectly, cut it off and form a new one. Refer to Fig. 5-11.

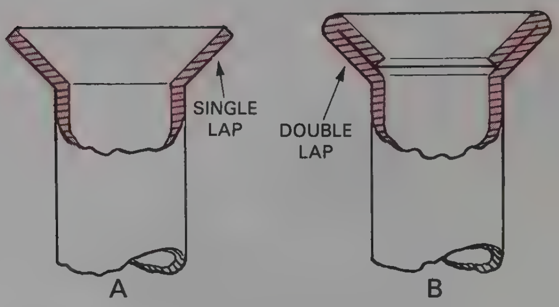

SINGLE LAP
DOUBLE LAP
A
B

Fig. 5-9. A—Single-lap. B—Double-lap flare.

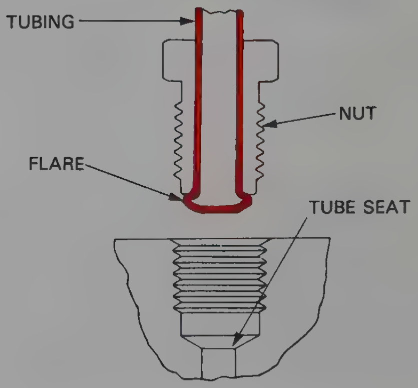

TUBING
NUT
FLARE
TUBE SEAT

Fig. 5-10. I.S.O. flare is becoming popular with many car manufacturers. (Chevrolet)

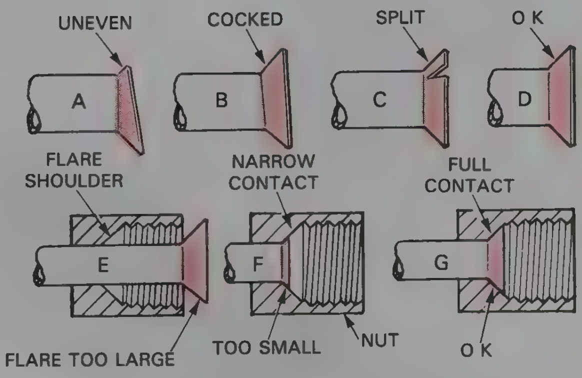

UNEVEN
COCKED
SPLIT
O K
A
B
C
D
FLARE SHOULDER
NARROW CONTACT
FULL CONTACT
E
F
G
FLARE TOO LARGE
TOO SMALL
NUT
O K

Fig. 5-11. Flare must be square with tube centerline and of correct size.

FORMING A DOUBLE-LAP FLARE

After cutting, reaming, and determining the proper flare angle, insert the tubing in a flaring tool. The tool shown in Fig. 5-12 will produce either a single or double-lap flare.

Always follow the instructions provided by the manufacturer of the tool. In general, you will find that the actual forming process is similar for all types.

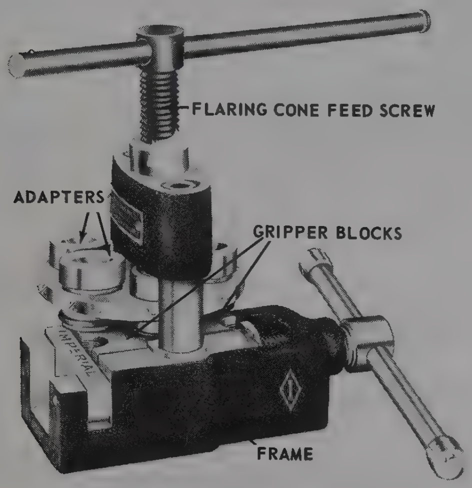

FLARING CONE FEED SCREW
ADAPTERS
GRIPPER BLOCKS
IMPERIAL
FRAME

Fig. 5-12. One type of flaring tool. This tool will produce both single and double-lap flares.

To use the tool illustrated in Fig. 5-12, arrange the gripping blocks so that the correct size tubing hole is directly beneath the flaring cone. Rotate the adapter plate until the correct size adapter is beneath the cone. Shove the tubing through the gripper blocks until it strikes the adapter. Tighten the block securely so the tubing cannot be forced downward under flaring pressure, Fig. 5-13.

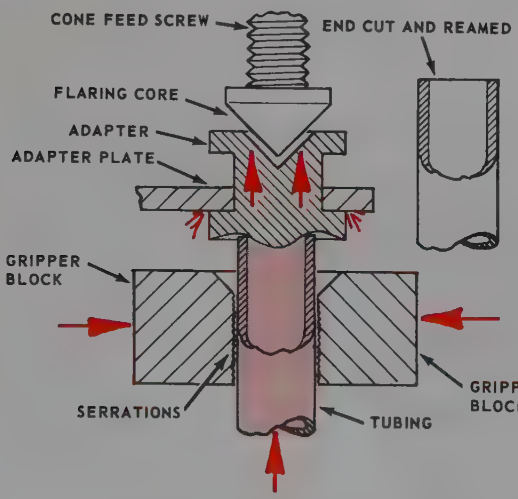

CONE FEED SCREW
END CUT AND REAMED
FLARING CORE
ADAPTER
ADAPTER PLATE
GRIPPER BLOCK
SERRATIONS
TUBING
GRIPPER BLOCK

Fig. 5-13. Insert tubing. Push tubing in until adapter strikes adapter plate. Then, tighten gripper blocks.

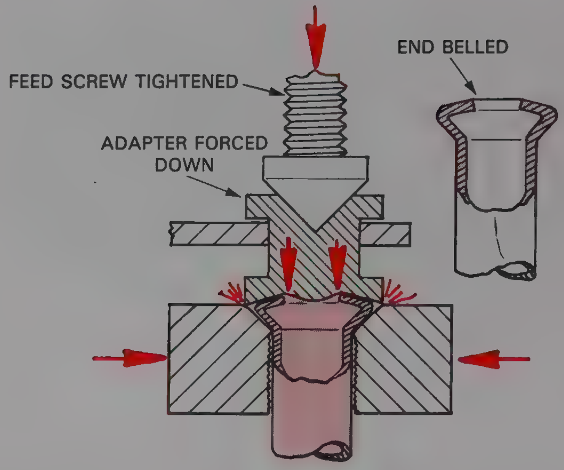

FEED SCREW TIGHTENED
END BELLED
ADAPTER FORCED DOWN

Fig. 5-14. Belling tube end. Tighten cone feed screw until adapter strikes gripper block.

Run the flaring cone down until it forces the adapter against the gripping block. This causes the adapter to BELL the end of the tubing. This is the first step in doing a double-lap flare, Fig. 5-14.

Turn the flaring cone back. Swing the adapter out of the way, and run the cone tightly down into the belled tubing. This will form the finished flare, Fig. 5-15.

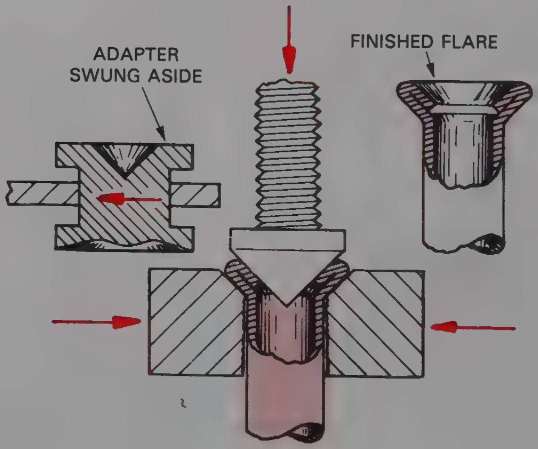

ADAPTER SWUNG ASIDE
FINISHED FLARE

Fig. 5-15. Finished flare. Adapter swung aside and cone forced into belled end.

FORMING AN I.S.O. FLARE

The I.S.O. flare, also called bubble flare, is produced with a tool similar to that used for making the double-flare. The flare is made in just one step. After you have selected, cut, and deburred the tubing, it is secured in the flaring tool by tightening the two wing nuts. The tool is then clamped by its tail in a vise.

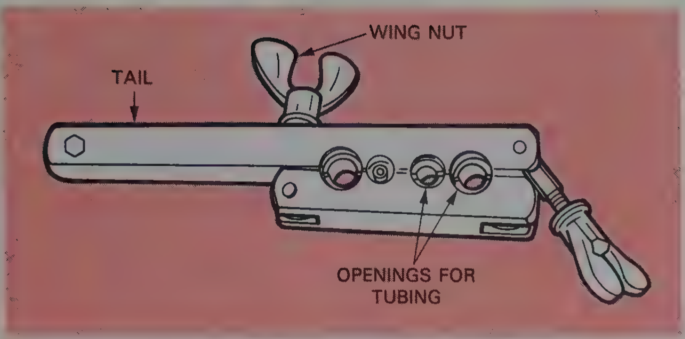


Fig. 5-16. One type of I.S.O. flare producing tool. This will only make I.S.O. flare. Do not try to make a single or double-lap flare with it, they are not interchangeable. (Niehoff)

Once in the vise, the anvil, similar to the one shown in Fig. 5-14, is forced down on the tube end. The anvil bends the end into the I.S.O. shaped flare.

When you are making any kind of tubing flare, be sure to follow the toolmaker's directions. One particular I.S.O. flaring tool is shown in Fig. 5-16.

REMEMBER - ALWAYS SLIDE THE FITTING NUT ON THE TUBING BEFORE FLARING, Fig. 5-17.

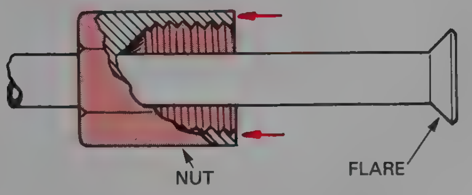


Fig. 5-17. Slide nut on tube before flaring.

CLEAN TUBING

After cutting, reaming, and flaring, use compressed air to blow out the line and remove any chips or other foreign material. Place the tubing in a clean spot until ready to install. If, during installation, there is any chance of dirt or grease being jammed into the ends, cover the ends with masking tape.

REMEMBER - THE SLIGHTEST AMOUNT OF FOREIGN MATERIAL MAY RUIN THE JOB. KEEP THE TUBING SPOTLESS!

BENDING TUBING

Soft copper and thin-wall steel tubing, in the more common sizes, can be bent by hand. Slip a bending spring over the tubing, then form the bend with your hands. When using a bending spring, make sure it is the correct size. Bend the tubing slightly more than needed. When it is bent to the exact shape, the spring can then be removed, Fig. 5-18.

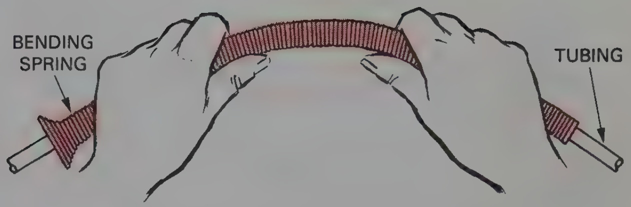


Fig. 5-18. Using a spring tube bender.

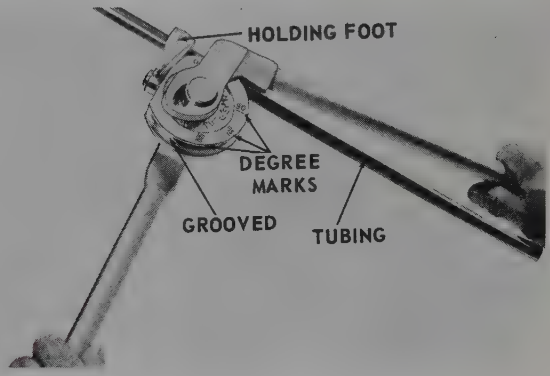


Fig. 5-19. Tubing inserted in mechanical bender.

Stiffer tubing may be handled with a lever-type bender. This tool will make uniform bends. When appearance is important, it is often used on softer tubing also. Fig. 5-19 shows tubing inserted in the tool. Note that the tool is marked in degrees to assist in controlling the amount of bend.

In Fig. 5-20, the handles have been closed and the tubing bent. The mechanic has opened the handles, loosened the holding foot, and is removing the tubing.

It is often advisable to bend tubing prior to flaring. However, if the bend must be close to the flare, make the flare first so the bend will not interfere with the flaring tool. To facilitate assembly, never start the bend too close to the flare. Allow about twice the length of the nut, Fig. 5-21.

REMEMBER - WHEN BENDING TUBING, BE VERY CAREFUL TO AVOID KINKS AND FLAT

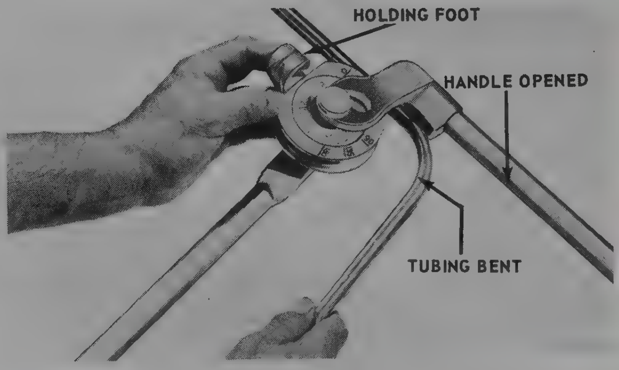


Fig. 5-20. Bend completed, handles open, tubing being removed. (Imperial Brass Mfg. Co.)

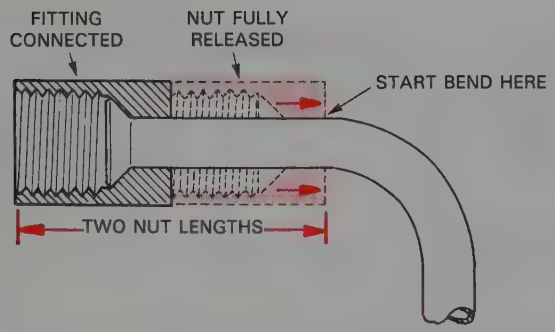

FITTING CONNECTED
NUT FULLY RELEASED
START BEND HERE
TWO NUT LENGTHS

Fig. 5-21. Allow enough space between fitting and bend so that nut will slide back as shown.

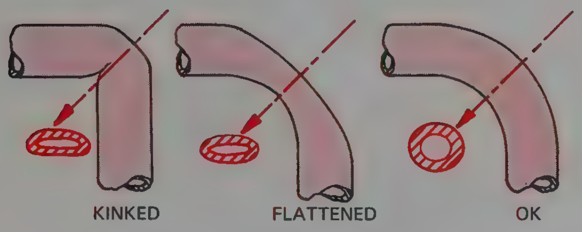

KINKED
FLATTENED
OK

Fig. 5-22. When bending, avoid kinking or flattening of tubing.

SPOTS! Once kinked or flattened, the tubing will restrict flow and lead to trouble. ALWAYS USE A SUITABLE BENDING DEVICE, Fig. 5-22.

INSTALLING TUBING

Tubing must usually be bent in one or more directions to provide a proper fit. To insure satisfactory service, a few important rules should be kept in mind prior to actual bending.

AVOID STRAIGHT RUNS

Straight runs, especially if short, will not work well. The slightest shifting between the two units will impose a strain on the connections. They are also difficult to install or remove, Fig. 5-23.

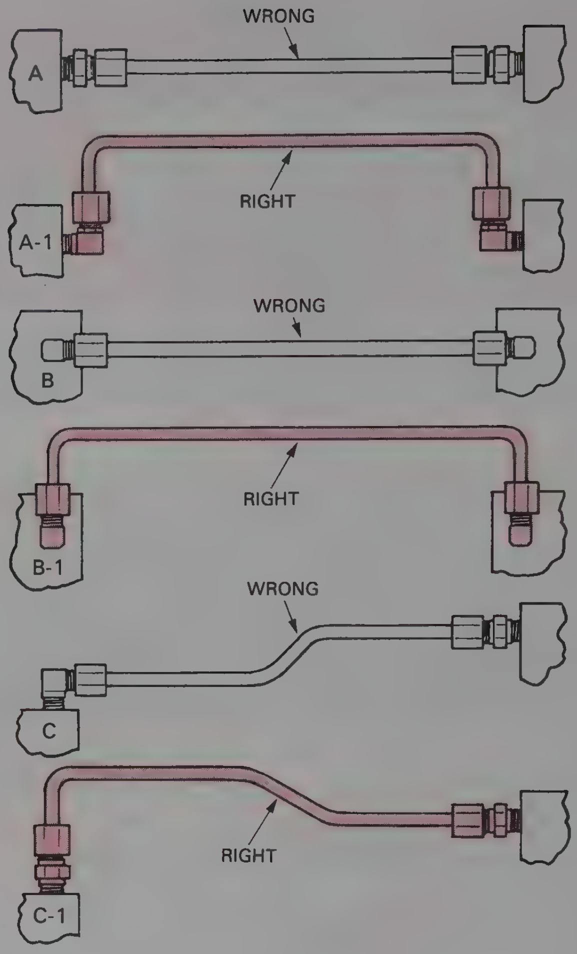

WRONG
A
RIGHT
A-1
WRONG
B
RIGHT
B-1
WRONG
C
RIGHT
C-1

Fig. 5-23. Avoid straight runs - A, B, C, by installing tubing as shown in A-1, B-1, and C-1.

SUPPORT LONG RUNS

Tubing can fail if subjected to excessive vibration. Secure long runs with clips or holddowns. Junction or distribution blocks and other heavy units must be supported, Fig. 5-24.

TUBING ENDS SHOULD ALIGN WITH FITTINGS

To prevent cross-threading (threads started and turned in a cocked position, ruining the threads), leaks,

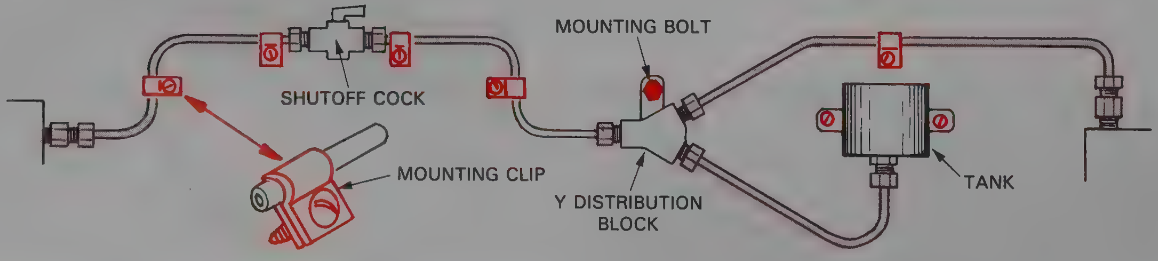

MOUNTING BOLT
SHUTOFF COCK
MOUNTING CLIP
Y DISTRIBUTION BLOCK
TANK

Fig. 5-24. Long tubing runs and related units must be supported with mounting clips and bolts.

and to facilitate installation, make sure tubing ends are in line with the fitting. The tubing should NOT have to be sprung into alignment. Fittings should start and run up several turns with finger pressure only. If they start hard, check for damaged threads, alignment, and size. DO NOT CROSS-THREAD THE FITTING. See Fig. 5-25.

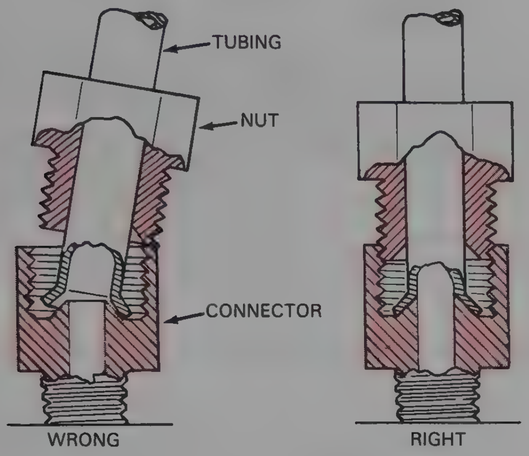


Fig. 5-25. Proper alignment is important. Nut on left would cross-thread.

DETOUR AROUND HOT SPOTS

Never run tubing too close to the exhaust system. Keep it as far away as possible. If necessary, install a heat baffle or insulate the tubing, Fig. 5-26.

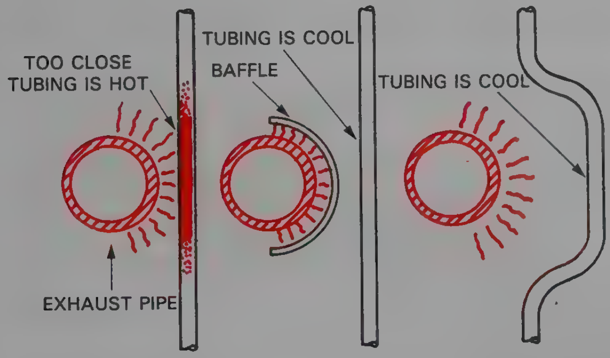


Fig. 5-26. Protect tubing from heating by either installing a heat baffle or rerouting.

ASSEMBLE BOTH ENDS BEFORE FINAL TIGHTENING

Connect the tubing long leg end first. Leave the fitting loose so that the other end can be moved enough to make the connection. Once BOTH connections are made, tighten. Use discretion when tightening. If

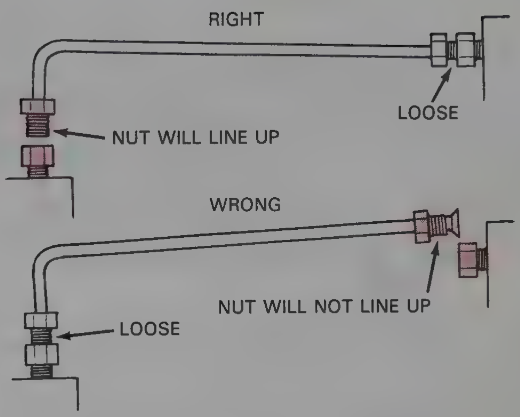


Fig. 5-27. Assemble tubing long leg end first. If short end is assembled first, other end will be difficult to connect.

torque values are available, use them. This chapter will give you general instructions on the amount of tightening needed.

REMEMBER: MANY FITTINGS ARE EASY TO TWIST OFF - BE CAREFUL. See Fig. 5-27.

FITTINGS

Proper selection of fittings is important. The correct choice will speed up the job and insure proper operation. Fittings are designed to make either a flared, compression, or pipe connection.

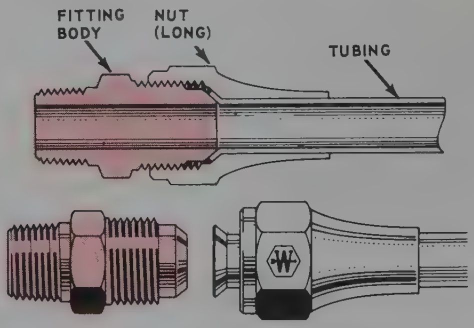


Fig. 5-28. SAE 45 deg. flare fitting. The nut threads over fitting body. (Weatherhead Co.)

The flare fitting just discussed can be of the SAE type, Fig. 5-28, or the INVERTED type, Fig. 5-29.

WHEN TO USE FLARE FITTINGS

Flared fittings CAN be used on any type of tubing (copper, aluminum, steel) that will lend itself to flaring. Flared fittings MUST be used on high pressure automotive applications such as the brakes and power steering.

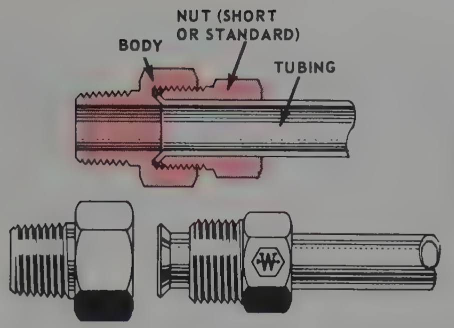


Fig. 5-29. Inverted 45 deg. flare fitting. Nut threads into fitting body.

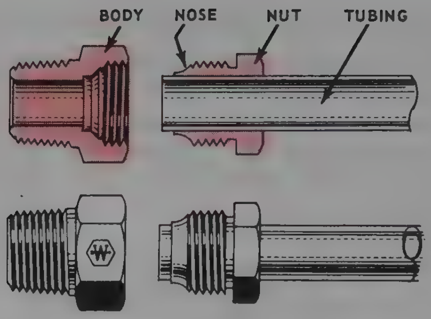


Fig. 5-31. Double compression fitting. When tightened, nose of nut is forced against tubing.

ASSEMBLING FLARED FITTINGS

Slide the nut, long or short depending on use, on the tubing. Flare the tubing making certain the flare is of the correct angle and width. Double-flare brazed steel tubing, thin-wall tubing, and all high-pressure applications.

Align the tubing with the fitting. Shove the flare against the fitting seat and run the nut up finger tight. Using a flare nut wrench, bring the nut up solidly. You will feel a firm metal-to-metal contact (flare securely pinched between nut and fitting body). At this point, give the nut an additional 1/6 turn.

FLARELESS COMPRESSION TYPE FITTINGS

A sleeve, either a separate unit or designed as part of the nut, is used in compression fittings. When the fitting and nut are drawn together, the sleeve is compressed against the tubing, fitting, and nut. The separate sleeve-type compression fitting is pictured in Fig. 5-30.

The DOUBLE COMPRESSION type, using the nose of the nut as the sleeve, is shown in Fig. 5-31.

WHEN TO USE COMPRESSION FITTINGS

Compression fittings may be used on low-pressure applications such as vacuum, fuel, and lubrication lines. Since no flaring is required, connections are quick and easy to make. DO NOT USE ON BRAKE AND POWER STEERING SYSTEMS.

ASSEMBLING COMPRESSION FITTINGS

Slide the nut, followed by the sleeve, on the tubing. When the tubing is aligned with the fitting, insert the tubing as far as it will go. While holding the tubing in, run up the nut finger tight. Using a flare nut wrench, bring the nut up until the sleeve just grasps the tubing. For tubing size 1/8, 3/16, and 1/4-in., give the nut an additional one and one-quarter turn. For 5/16-in. tubing, use one and three-quarter turn and for all sizes 3/8 to 1-in., two and one-quarter turns. WHILE TIGHTENING, HOLD THE TUBING IN THE FITTING!

The foregoing tightening procedure applies only to new compression fittings. When assembling USED fittings, bring the nut up firmly with no additional turns.

PLASTIC TUBING COMPRESSION FITTINGS

When RIGID plastic tubing is used, a regular separate sleeve compression fitting will suffice. However, if the tubing is SOFT, a special insert is placed in the end so the sleeve will not crush the tube, Fig. 5-32.

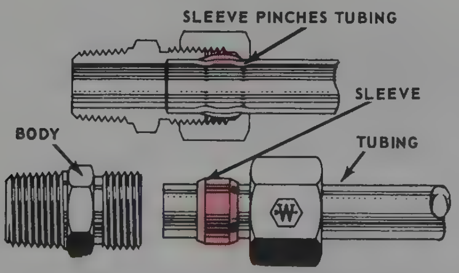


Fig. 5-30. Separate sleeve compression fitting. Notice how upon tightening, sleeve pinches tubing.

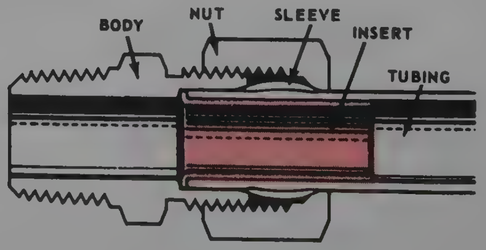


Fig. 5-32. Fitting for soft plastic tubing. Insert is needed to prevent sleeve from crushing tubing.

OTHER SPECIALIZED COMPRESSION TYPES

One type of compression fitting, designed for resistance to extreme vibration, is shown in Fig. 5-33. Instead of the conventional metal sleeve, a composition sleeve material is used. Note how the tube can flex without bending. This fitting is for low-pressure use.

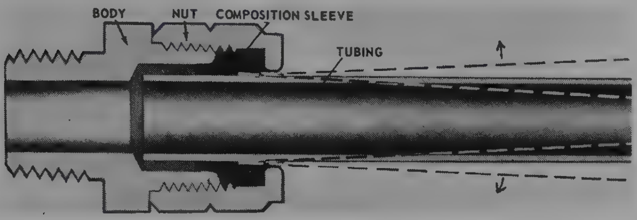


Fig. 5-33. Flexible compression fitting. Composition sleeve allows heavy vibration without imposing an undue strain on tubing.

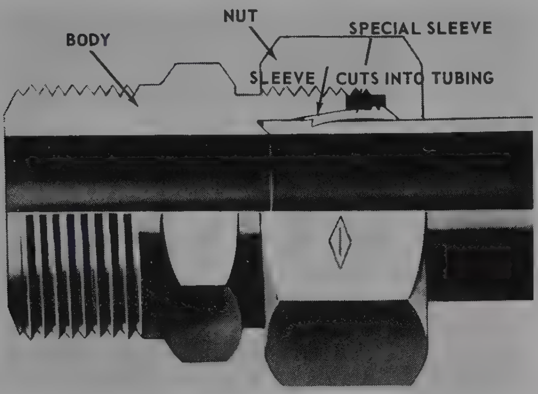


Fig. 5-34. Ermeto high-pressure compression fitting. (Imperial Brass Mfg. Co.)

The Ermeto is a compression type fitting designed to withstand high pressure. Heavy, difficult to flare tubing may be handled with this design, Fig. 5-34.

Another compression type fitting that will handle high pressure is shown in Fig. 5-35.

NUT LENGTH

Nuts for both flare and compression fittings are available in both standard and long versions. Where the installation is subjected to heavy vibration, use the long nut. This will tend to support the tubing a greater distance from the actual connection. Fig. 5-36 illustrates a compression-type UNION using the standard nut. The long nut, on a similar union, is used in Fig. 5-37.

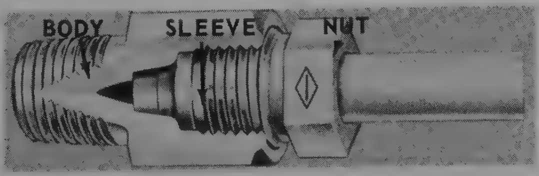


Fig. 5-35. This compression fitting is designed for high pressure.

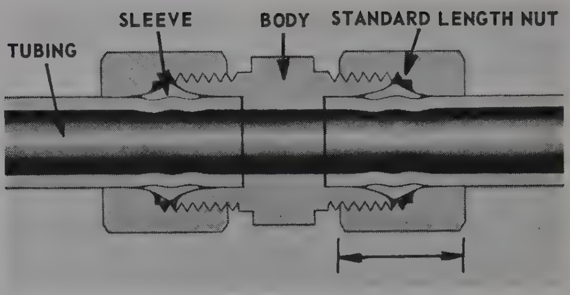


Fig. 5-36. Compression type union using standard length nut.

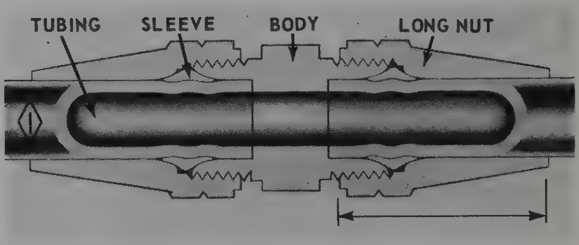


Fig. 5-37. Compression type union using long length nut.

PIPE FITTINGS

The pipe fitting uses a tapered thread that produces leakproof joints. A development in pipe threads, called the DRYSEAL PIPE THREAD, produces leakproof joints without undue turning force. This is accomplished by a difference in the truncation (cutoff point) of the thread root and crest. As the fitting is drawn together, the root (bottom) and crest (top) of the threads come in contact before the flanks (sides). Final tightening causes metal-to-metal contact between root, crest, and flank. Fig. 5-38 shows a section of steel pipe

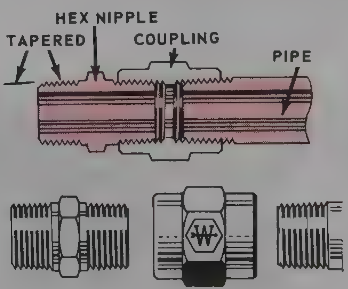


Fig. 5-38. Pipe fitting. Note tapered threads. (Weatherhead Co.)

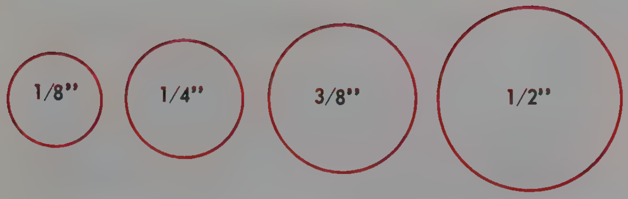


Fig. 5-39. Actual OD for pipe fitting ends for tubing sizes as shown.

joined to a hex NIPPLE by using a COUPLING. Note the tapered threads.

PIPE THREAD SIZE

Fig. 5-39 shows the actual diameter of the pipe thread ends used on tubing fittings.

ASSEMBLING PIPE FITTINGS

After firm hand tightening, providing the threads are clean, give the fitting about three additional turns. This will lock the threads. Tightening beyond this point will be of no value and could even split the fitting.

Thread sealing compound (type compatible with system) should be used on critical applications. Use sparingly.

FITTING DESIGN

There are a number of various shaped fittings designed to handle all types of installations. The mechanic should be familiar with the following basic designs and their use.

CONNECTORS

Connectors are used to attach the tubing to a unit such as a carburetor, fuel pump, or oil filter. They can also be used to connect the threaded end of a pipe to a flare or compression fitting, Fig. 5-40.

UNIONS

A union is designed to connect two or more sections of tubing. It can be disassembled without turning the tubing, Fig. 5-41.

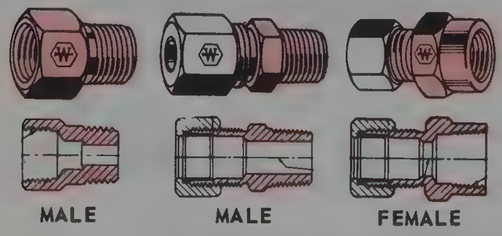


Fig. 5-40. Typical compression type connectors.

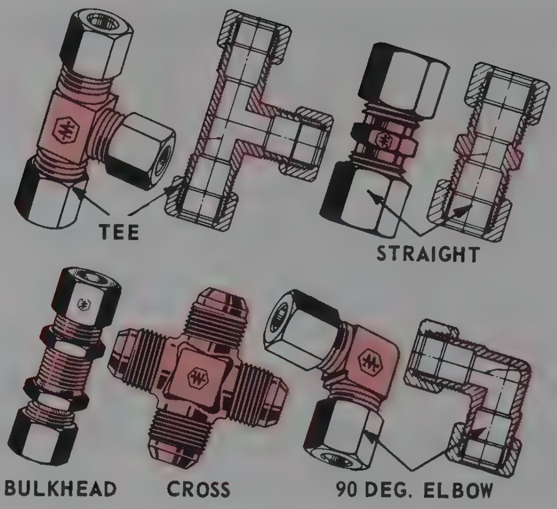


Fig. 5-41. Typical compression type unions.

ELBOWS

When a line must leave the unit at an angle, 90 or 45 deg. male or female elbows are used. Female refers to a fitting with an internal thread. The male fitting has an external thread, Fig. 5-42.

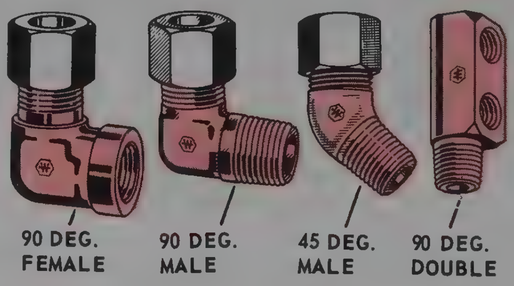


Fig. 5-42. Typical compression type elbows.

T-FITTINGS

A T-fitting is a handy fitting to use where branch lines are necessary. The two common types are the BRANCH-T and the RUN-T. Male and female types are available, Fig. 5-43.

PIPE FITTINGS

Common pipe fittings are illustrated in Fig. 5-44. Note that all connections are threaded. No flare or compression sleeves are needed.

SWIVEL FITTINGS

One end of this type fitting utilizes a swivel nut. These are available in straight connectors, elbows, and tees. See Fig. 5-45.

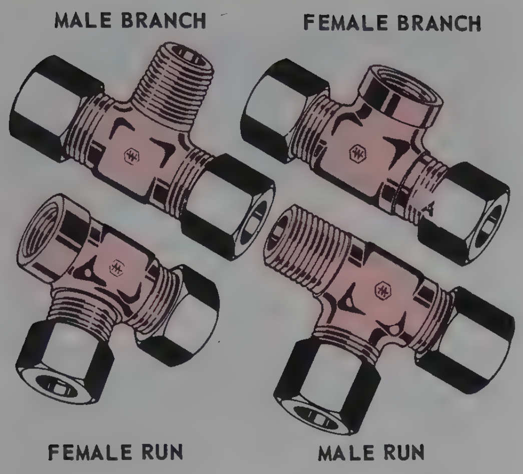

MALE BRANCH
FEMALE BRANCH
FEMALE RUN
MALE RUN

Fig. 5-43. Compression type T-fittings.

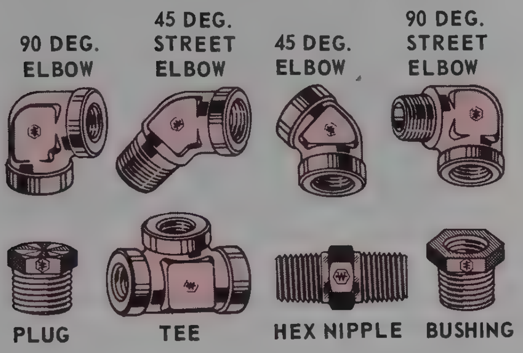

90 DEG. ELBOW
45 DEG. STREET ELBOW
45 DEG. ELBOW
90 DEG. STREET ELBOW
PLUG
TEE
HEX NIPPLE
BUSHING

Fig. 5-44. Pipe fittings.

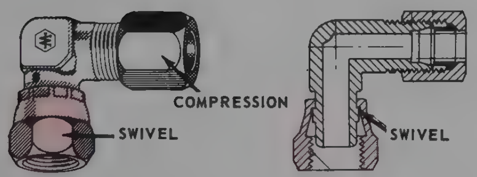

COMPRESSION
SWIVEL
SWIVEL

Fig. 5-45. Elbow with swivel nut.

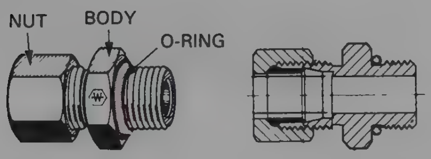

NUT
BODY
O-RING

Fig. 5-46. O-ring connector. Note straight, not pipe, threads.

O-RING FITTING

The O-ring fitting uses straight threads and depends on an O-ring to prevent leaks. A straight O-ring connector is shown in Fig. 5-46. The elbow design, Fig. 5-47, makes it possible to position the elbow at any angle. It is held at the selected angle and the lock nut tightened. This crushes the O-ring and seals the fitting.

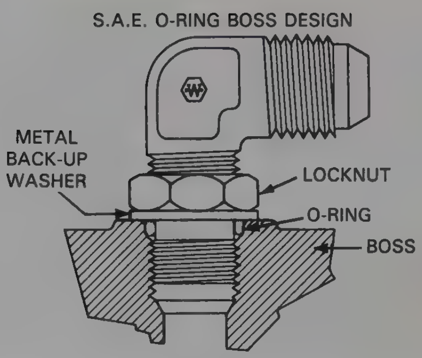

S.A.E. O-RING BOSS DESIGN
METAL BACK-UP WASHER
LOCKNUT
O-RING
BOSS

Fig. 5-47. 90 deg. O-ring adjustable elbow.

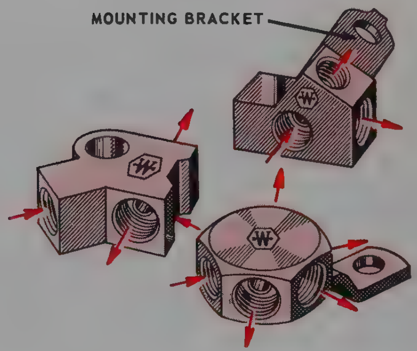

MOUNTING BRACKET

Fig. 5-48. Typical distribution blocks.

JUNCTION OR DISTRIBUTION BLOCKS

When several branch lines are served by a single feeder line, a DISTRIBUTION BLOCK can be used. A distribution block is usually fitted with a mounting bracket, Fig. 5-48.

SHUTOFF AND DRAIN COCKS

The SHUTOFF COCK is used to stop flow through a line. A DRAIN COCK is used to draw off the contents. When using these fittings, install so that when in the off position, the fluid flow is against the seat and not the threads. This prevents the threads, especially in radiator drain cocks, from becoming corroded and difficult to turn, Figs. 5-49 and 5-50.

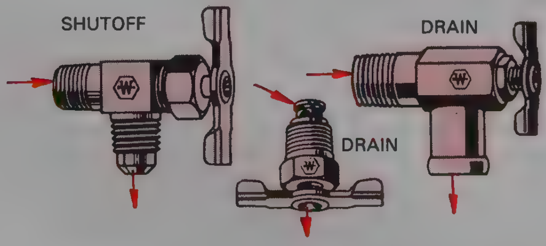

SHUTOFF
DRAIN
DRAIN

Fig. 5-49. Shutoff and drain cocks.

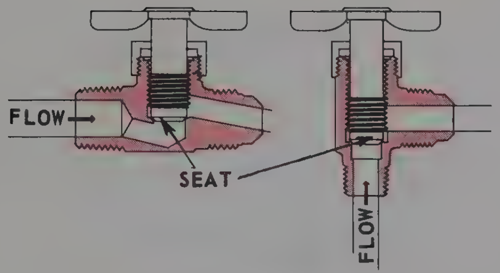


Fig. 5-50. Flow is against seat. Both shutoff cocks are in the closed position. (Weatherhead Co.)

HOSE

Numerous sections of hose, both low and high-pressure, are used on the modern automobile. They are generally identified by use, pressure capacity, method of construction, and materials used.

Hose, properly installed, will withstand vibration and flexing (within limits).

The cooling, lubrication, fuel, vacuum, steering, and brake systems all utilize some flexible hose in their design. It is important that the mechanic know what replacement types are needed and the correct methods of installation.

COOLING SYSTEM AND HEATER HOSE

Pressures are relatively low so the hose used in both the cooling and heating systems is generally of a single or double-ply construction. For heavy-duty applications, heavier hose is available.

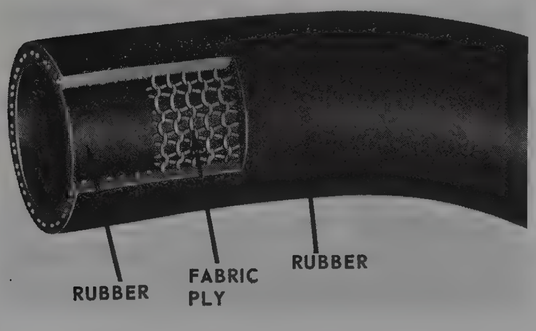


Fig. 5-51. Section of single ply, molded radiator hose. (Gates Rubber Co.)

Radiator hose is available in straight (can be bent only a trifle), curved (moulded into the appropriate shape), and flexible (designed to withstand considerable bending without collapsing) types. It often has a built-in spiral of wire to prevent collapse. The bottom radiator hose is particularly susceptible to collapse due to the vacuum created by the water pump.

Figs. 5-51 and 5-52 illustrate the typical moulded and flexible radiator hose. Fig. 5-53, an enlarged cutaway, shows the fabric ply and spiral wire construction.

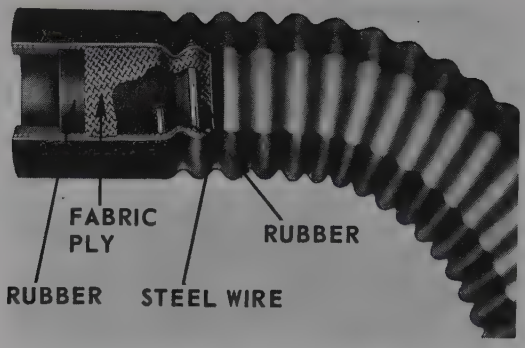


Fig. 5-52. Section of flexible radiator hose. Note built-in wire spiral.

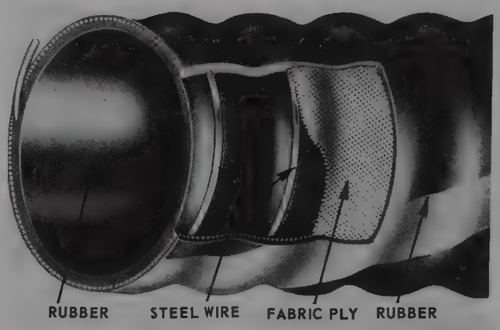


Fig. 5-53. Typical flexible radiator hose construction. Fabric ply and spiral wire are molded between two layers of rubber.

FUEL SYSTEM HOSE

Fuel systems operate on both high and low pressures. Therefore, the correct type of fuel system hose must be used. Never use single-ply, synthetic hose in fuel injection systems. The high pressure in these systems can cause a single-ply hose to rupture. NEVER USE HOSE THAT IS NOT SPECIFICALLY DESIGNED TO WITHSTAND FUEL! See Fig. 5-54.

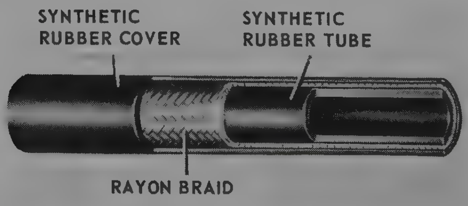


Fig. 5-54. Fuel system hose construction. Hose sidewalls are relatively thick to prevent collapse under vacuum. (Gates Rubber Co.)

POWER STEERING AND BRAKE HOSE

Power steering and brake systems create pressures exceeding 1000 psi (6 895 kPa). The hose used must be of multiple-ply construction. Replacement hoses are readily available. DO NOT MAKE UP HOSES FOR THESE SYSTEMS. USE REPUTABLE FACTORY REPLACEMENTS, Fig. 5-55.

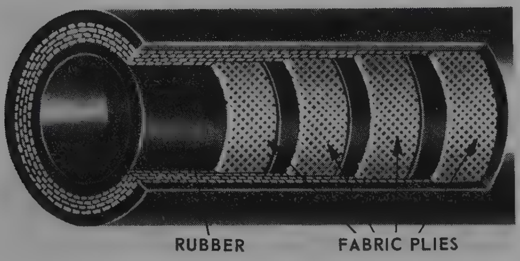

RUBBER
FABRIC PLIES

Fig. 5-55. Multiple-ply high pressure hose. Keep in mind that ply thickness, number of plies, material, and weave must be considered in determining the working pressure.

LUBRICATION HOSE

When used, oil filter hoses can either be made up or purchased ready made. The filter hoses shown in Fig. 5-56 utilize a synthetic rubber hose covered with a soft wire braid for pressure strength. Fabric ply lines are also used. The hose must be oil resistant, Fig. 5-56.

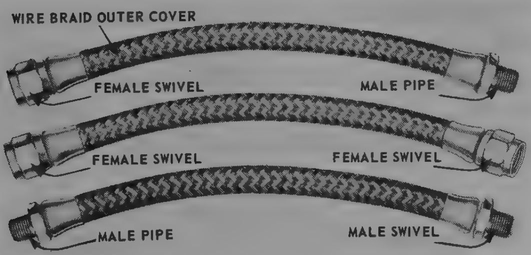

WIRE BRAID OUTER COVER
FEMALE SWIVEL
MALE PIPE
FEMALE SWIVEL
FEMALE SWIVEL
MALE PIPE
MALE SWIVEL

Fig. 5-56. Oil filter hose lines. Note use of an outer cover of soft woven wire to provide strength. (Edelmann & Co.)

NONREINFORCED HOSE

Many of the smaller diameter vacuum, windshield washer, drain, and overflow hoses are made of rubber with no reinforcing.

HOSE END FITTINGS

There are numerous types of end fittings. Fig. 5-57 pictures a number of reusable (can be taken off and remounted on new hose) hose fittings. Notice they include pipe, 37 and 45-deg. flare types.

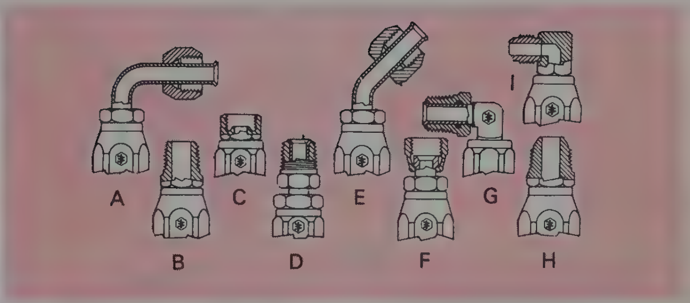


Fig. 5-57. Reusable hose ends. A—90 deg. tube elbow. B—Male pipe. C—Inverted flare, rigid. D—Inverted flare. E—45 deg. tube elbow. F—Swivel. G—90 deg. elbow flare. H—37 deg. J.I.C., rigid. I—90 deg. elbow flare, rigid. (Weatherhead Co.)

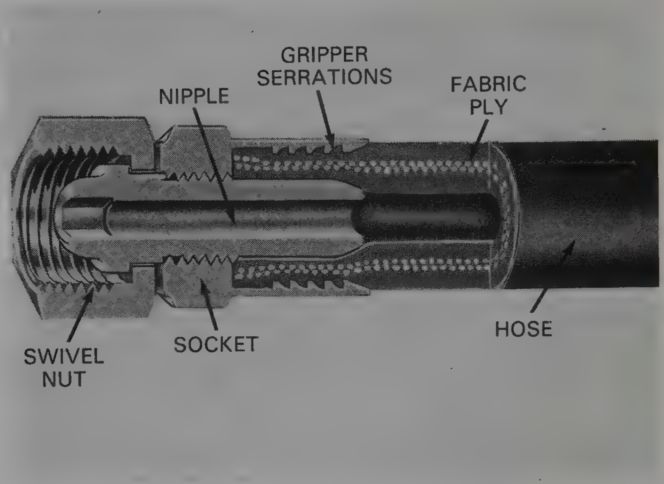

GRIPPER SERRATIONS
NIPPLE
FABRIC PLY
SWIVEL NUT
SOCKET
HOSE

Fig. 5-58. High-pressure reusable hose end construction. Note how nipple forces hose into gripper serrations.

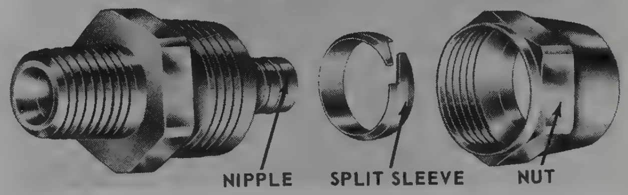

NIPPLE
SPLIT SLEEVE
NUT

Fig. 5-59. Low pressure hose end construction. The split sleeve forces inside of hose against nipple.

Reusable fittings shown in Figs. 5-58 and 5-59 are typical.

HOSE END INSTALLATION

Fig. 5-60, detail A, shows a simple Barb type.

1. Lubricate the hose and fitting. DO NOT USE A LUBRICANT THAT WILL ATTACK THE HOSE OR CONTAMINATE THE SYSTEM!
2. Shove the hose completely over the barbed end.

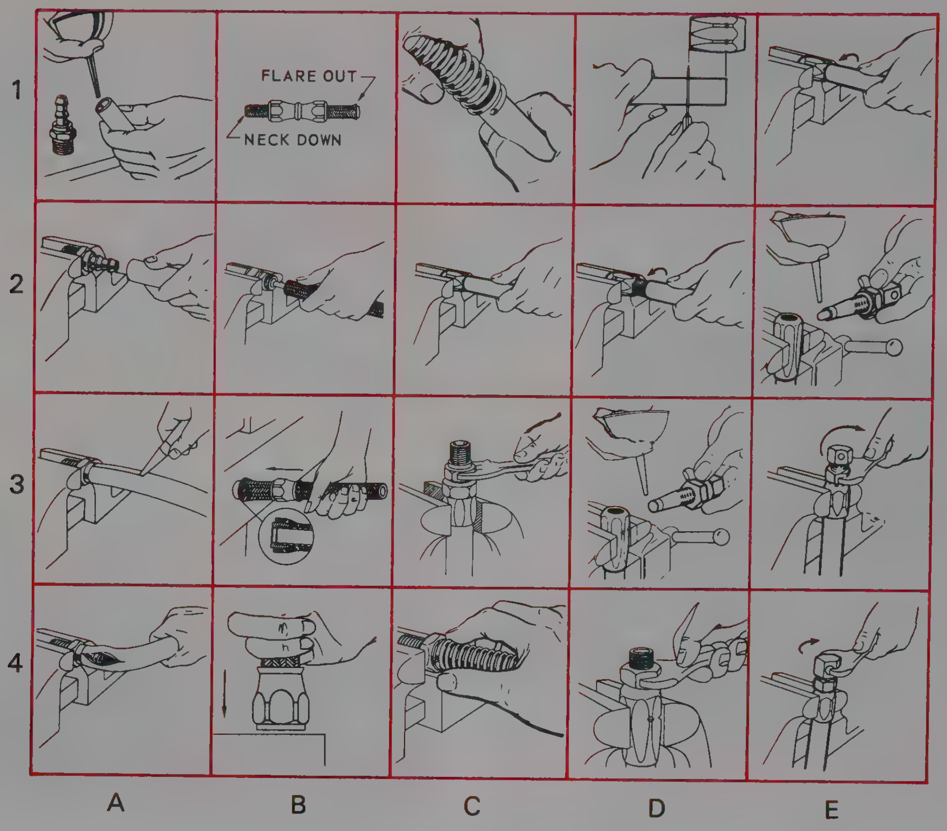


Fig. 5-60. General method of attaching various types of hose ends. (Imperial Brass Mfg. Co.)

3. Remove by cutting the hose.

Fig. 5-60, detail B, illustrates a compression fitting used for wire braid hose.

1. One end of the braid is necked down and the other flared. The nuts are installed.
2. The hose is installed over the nipple to adapt it to size, and is then removed.
3. Insert is placed over hose and under braid. Hose is shoved against flat surface to seat insert fully.
4. Nuts are pushed over insert, hose shoved over nipple, and nuts tightened.

Fig. 5-60, detail C.

1. Air brake hose spring slid over hose.
2. Hose pushed into socket.
3. Nipple threaded into socket squeezing hose between nipple and socket.
4. Spring snapped over socket shoulder.

Fig. 5-60, detail D.

1. Hose marked and skived (outer layer of rubber removed down to first layer of cord). BE CAREFUL NOT TO CUT CORD.
2. Skived end shoved into socket.
3. Nipple and hose lubricated.
4. Nipple threaded into socket.

Fig. 5-60, detail E.

1. Hose shoved into socket.
2. Mandrel (pilot to expand hose and assist in proper seating) lubricated.
3. Nipple threaded in.
4. Mandrel seated and then removed.

When assembling hose ends, always lubricate with water, soap, oil, brake fluid, air conditioning compressor oil, or other agent compatible with the system. Directions given for fittings in Fig. 5-60 are general.

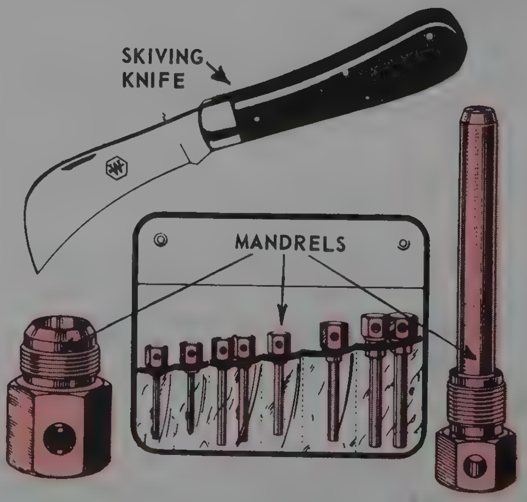


Fig. 5-61. Skiving knife and mandrel set. These are essential tools for proper installation of certain type hose ends.

Always follow the particular manufacturer's instructions. A skiving knife and mandrel set are shown in Fig. 5-61.

SKIVED HOSE

As mentioned, when instructions call for skiving a hose, be careful not to cut the cord. A fitting using a skived section is shown in Fig. 5-62. Skive only that portion necessary. The skived portion should not extend out of the fitting.

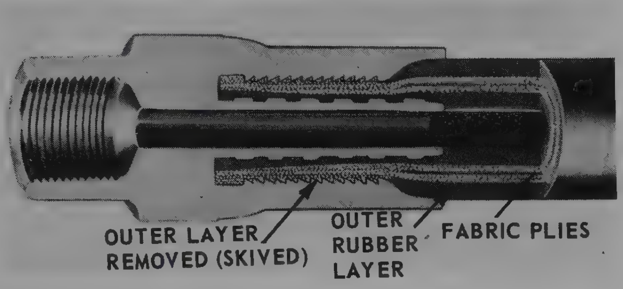


Fig. 5-62. Permanent (not reusable) hose end. Note skived section.

MOUNTING HOSES

Avoid sharp or double bends and twisting as this tends to cause premature failure. In determining how sharp a hose bend may be, figure that the radius of the bend should be AT LEAST FIVE TIMES the outside diameter of the hose. For example: A hose with an OD of 1/2 in. should have a bend radius of 2 1/2 in. In other words, if the hose were pulled around a circle, the circle would be at least 5 in. in diameter.

When making straight run connections, allow some slack to avoid stressing the hose from pressure, vibration, or part shifting.

When tightening hose fittings, tighten the swivel end last. Always support one portion with one wrench while tightening with another to prevent twisting the hose. Use flare wrenches.

Fig. 5-63 illustrates some typical hose installations. Those in the left column are WRONG. The correct methods are shown in the right column. Notice how single, smooth bends, without twisting, are made, Fig. 5-63.

Keep hoses away from the exhaust system. If the hose run is long, use clips to secure it in place. On off-highway vehicles, keep hoses and tubing well up within the frame to prevent snagging and shield them from flying rocks.

HOSE CLAMPS

In low pressure hose installations, such as the heater and radiator, the hose is merely slid over the fitting. A spring or screw-type clamp is then installed. Use a small amount of sealer to ease installation and to provide extra protection against leaks. Locate the clamps so that they may be easily reached for tightening. Tighten securely.

If the hose fitting has a raised rib, make sure the clamp is installed on the fitting side of the rib. This

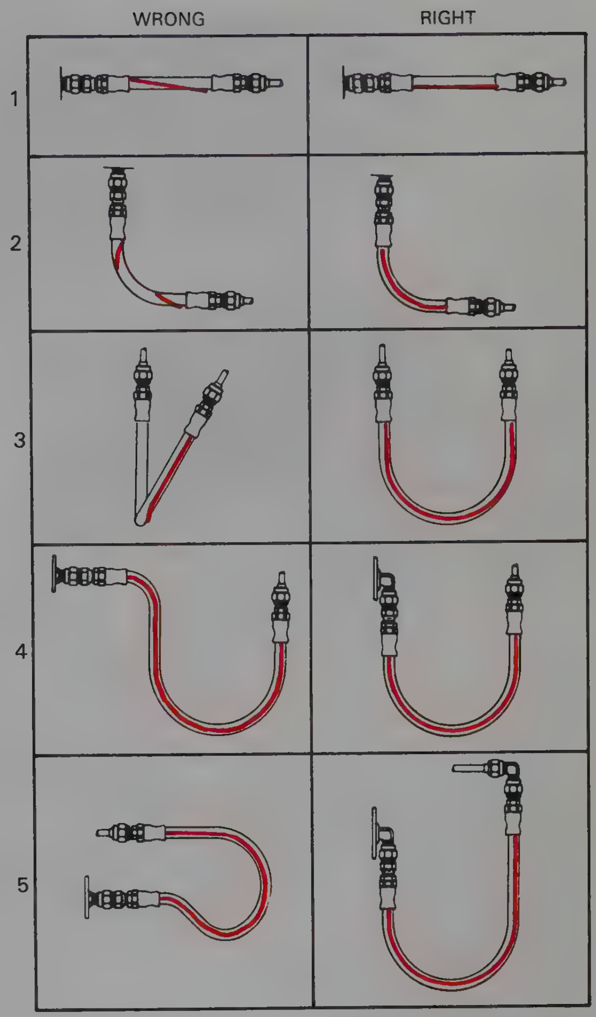


Fig. 5-63. Incorrect and correct hose installations. Double bends and twisting are to be avoided.

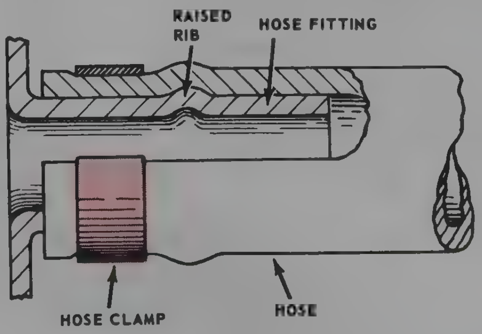


Fig. 5-64. Install hose clamp on the fitting side of the raised rib.

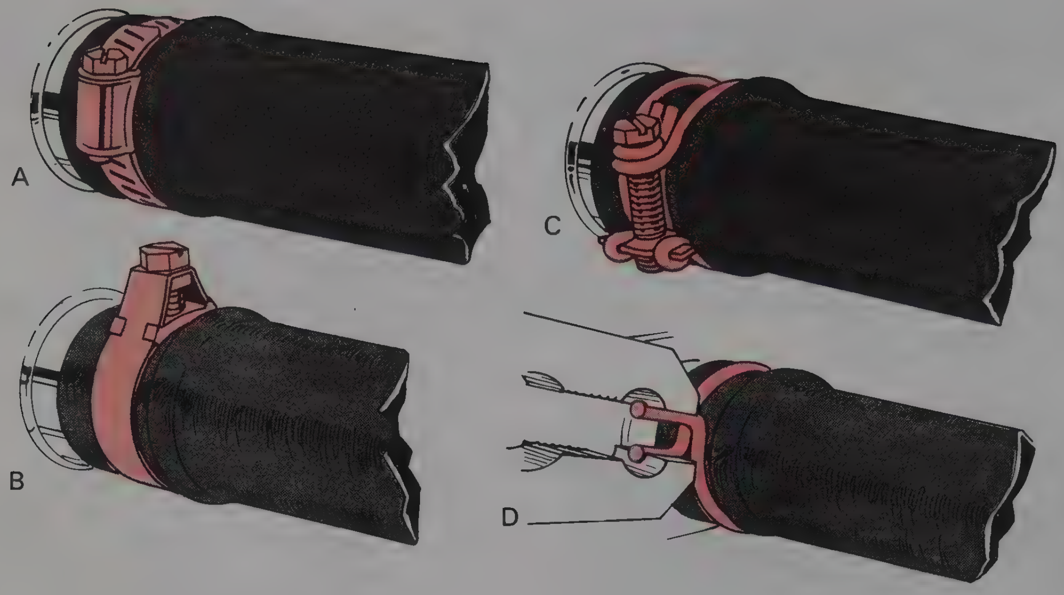


Fig. 5-65. Hoses can be secured by the following: A—Worm-drive clamp. B—Screw-tower clamp. C—Twin-wire clamp. D—Spring clamp. (Gates Rubber Co.)

will prevent the hose from working loose, Fig. 5-64.

Fig. 5-65 illustrates four methods of attaching a hose. Some clamps must be discarded after use.

If difficulty is experienced when attempting to remove an old hose, split the portion of the hose over the fittings. In short runs, it is helpful to split the full length of the hose.

HOSE CONDITION

Any hose that shows signs of cracking, undue softness, or swelling should be replaced. Hoses often deteriorate inside causing portions to break loose, producing partial or even complete blockage. CHECK HOSES CAREFULLY AND IF AT ALL DOUBTFUL, REPLACE THEM!

STORING HOSE SUPPLIES

Store hose in a cool spot. Avoid exposure to sunlight, fuel, lubricants, and chemical compounds.

SUMMARY

Copper, steel, aluminum, and plastic tubing are used in automotive work. Brake and steering systems MUST use double-wrapped, brazed steel tubing. Handle tubing carefully.

Tubing should be cut with a tube cutter. Bending should be done with either a spring or mechanical bender. Tubing ends must be square and all burrs removed.

Connections are made with either flared, compression, or pipe fittings. Flare fittings, 37 and 45-deg., SAE, and inverted, use a flare that must be formed with a flaring tool. Double-flare all double-wrapped steel tubing. Double-flare all high pressure applications.

When installing tubing, avoid straight runs. Support long runs and related parts. Protect from heat. Assemble both ends loosely before final tightening.

Compression fittings, sleeve, and double compression types, are quick, easy, and suitable for fuel, lubrication, and vacuum lines. When tightening, be sure to hold tubing all the way in the fitting. Compression fittings on soft plastic tubing require a special insert. Both standard and long nuts are available.

Pipe fittings use a tapered thread. They produce a seal through metal-to-metal contact when tightened.

Connectors, unions, elbows, tees, O-ring, distribution blocks, shutoff, and drain cocks are the commonly used fitting types. They are available for either flared, compression, or pipe connections.

Automotive type hose uses rubber, Neoprene, Buna, and other synthetic compounds in its construction. Nonreinforced, single, and multiple-ply types are needed.

Radiator hose is either straight, molded, or flexible. Fuel line hose must be resistant to gasoline and unless plastic is used, should have a reinforcing ply. Lubrication system hose must be reinforced and oil resistant.

Power steering and brake hoses use multiple-ply construction. Do not make up these hoses—buy quality replacements.

Vacuum wiper, overflow, windshield washer, and other applications often use plain, nonreinforced hose.

Hose end fittings can be classed as permanent or reusable.

Some hoses are attached with clamps or clips, Fig.

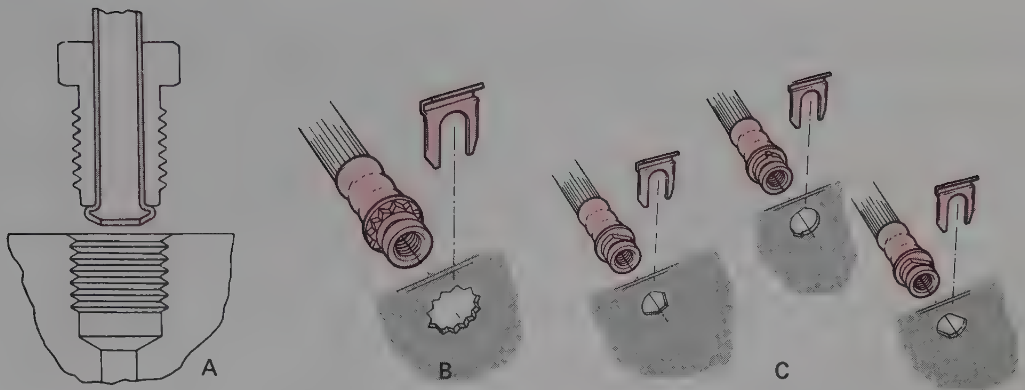


Fig. 5-66. A—I.S.O. type of flare. B and C—Various hose fitting mounting flange shapes. (Chevrolet)

5-66. Barb type fittings, where used, provide sufficient holding power. Threaded hose fittings can be of the flare, compression, or pipe type.

When installing hoses, avoid double bends, twisting, and sharp bends. Protect from heat, moving parts, and road damage.

Split old hoses (barb and clamp types) for easy removal.

Both hose and tubing must be clean before installation. Where sealant or lubrication is used, it must be compatible with the system involved. Support fittings with a wrench when tightening connections. Tighten swivel ends last. Use flare nut wrenches. Always test the finished job for leaks or malfunctions.

Protect stored tubing and hose from damage.

SUGGESTED ACTIVITIES

1. Cut off a piece of copper tubing using a hacksaw. Cut another piece using a tubing cutter. Is there a difference in the appearance? Which one made the best cut?
2. Ream and double-flare the end of a piece of brazed tubing. Follow the tool manufacturer's instructions.
3. Try to make a tight 90 deg. bend in a piece of copper tubing with your hands. Did the tubing remain round? Try it with both a spring and mechanical bender.
4. Carefully go over a car looking for tubing and hose fittings. Make a complete list of the different ones - elbows, connectors, tees. How many did you find?
5. Check the same car for different types of hose. List each hose, the system it serves, type, and method of attachment.

SIMPLE JOBS

Flaring tubing is a simple job compared to reboring an engine. Measuring the diameter of a crankshaft is a breeze in relation to obtaining the proper mesh in a set of differential gears. Selecting the proper fastener - not very complicated. Picking the right tool - nothing to it.

In that these, and many other jobs, are relatively simple, students often tend to overlook their significance and when studying a textbook or working in the shop, concentrate only on what they feel are the IMPORTANT jobs.

The experienced mechanic, who each day performs many so-called simple jobs, will be quick to inform you that the simple jobs are very important. Many major service jobs have failed due to careless or improper handling of the simple steps.

As regards to the simple job, remember these FACTS:

1. They MUST BE done.
2. They must be done CORRECTLY.
3. Somewhere along the line, you will have to LEARN HOW TO DO THEM!

Keep this in mind as you study this and other texts. Read EVERYTHING carefully and consider EVERYTHING you read IMPORTANT. You will be glad you did!

KNOW THESE TERMS

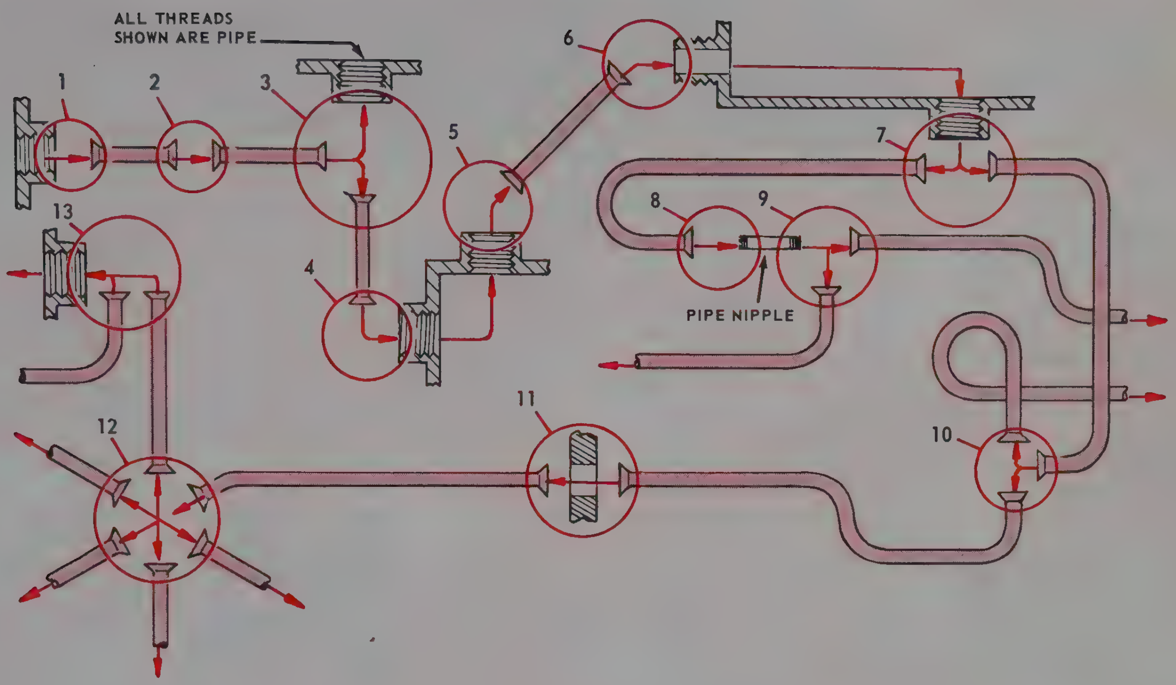
Double wall construction, Work hardening, Tubing cutter, Reamer blade, Tubing connections, Single lap flare, Double lap flare, I.S.O. flare, Flaring tool, Elbow, T-fitting, Distribution block, Drain cock, PSI, kPa, Neoprene, Bending spring, Hold-down clip, Cross-threading, Flared fitting, Heat baffle, Inverted flare, Double compression fitting, Union.

QUIZ - Chapter 5

1. Tubing is widely used in automobiles. [✓ True] or False?
2. The two most commonly used tubing materials are copper and Steel.

3. When removing tubing from a roll, lay the roll flat on the bench and pull the free end upward. True or [✓ False]?
4. The more tubing is worked, the softer it becomes. True or False?
5. Double-wrapped, tin-plated brazed steel tubing is suitable for brake line work. [✓ True] or False?
6. Plastic tubing cannot be used for any automotive work. True or [✓ False]?
7. A cutting tubing is ideal for cutting tubing.
8. After cutting, remove burrs and while doing this, hold the tubing end downwards.
9. To make satisfactory connections, tubing must be cut squarectly.
10. Always use flaring double-wrapped steel tubing.
11. What are two flare angles? 37° 45°
12. What is the first forming step called when making a double-lap flare? bell
13. As long as the flare is the correct angle, it can be slightly cocked to one side. [✓ True] or False?
14. The fitting nut should be placed on the tube before flaring.
15. Tubing can best be bent by using either a lever type or a spring bender.
16. A few particles of dirt or metal, as long as they are small, can be left in the tubing without harm. True or [✓ False]?
17. Straight runs of tubing should be made whenever possible. True or [✓ False]?
18. When installing, connect the long leg first.
19. If you force fittings that start hard, you will cross thread them.
20. When fittings are properly aligned, they may be given run up several turns by hand before a wrench is needed.
21. When making long tubing runs, be certain to support the tubing.
22. Always use Flarenut Wrench to tighten tubing fittings.
23. What is the basic difference between an SAE flare and an INVERTED flare fitting? SAE - thread over fitting thread inside.
24. Tubing bends should start at least twice length of the fitting nut from the actual connection.
25. Brake line and power steering tubing should be double rape.
26. Name two types of compression fitting. Ermeto - rigid
27. Compression fittings are generally used where low pressures are encountered.
28. When using a sleeve compression fitting on soft plastic tubing, an special insert is necessary.
29. On a flare fitting, after bringing the nut up solidly, how much more of a turn of the wrench is required? 1/6
30. On new compression fittings, how much should the wrench be turned after the sleeve grasps the tubing - for 1/8 - 1/4 in., for 5/16 in., and for 3/8 to 1 in.? 1/4 1 1/4 1 3/4
31. After firm hand tightening, how many turns are necessary for pipe fittings? 3 turns
32. The emetor compression fitting WILL handle high pressure.
33. As opposed to the standard nut, the long nut provides better resistance to ________.
34. Install drain cocks so that the confined fluid rests against the seat and not the ________.
35. Pure rubber hose would make a fine fuel line connection. [✓ True] or False?
36. Name three basic types of radiator hose.
37. Double bends will prolong the life of the hose. True or [✓ False]?
38. Brake hoses are of ________ ply construction.
39. It is not necessary to secure long runs of hose. True or [✓ False]?
40. Barb type hose fittings use clamps. True or False?
41. What is meant by skiving a hose?
42. In determining how sharp a bend in a hose should be subjected to, what handy rule would you use?
43. If a hose looks good on the outside, it will surely be good on the inside. True or [✓ False]?
44. A small amount of silicon will make radiator hose installation easier and will help to prevent seepage.
45. Describe three types of hose clamps.
46. Hose should be stored in a warm dry area. True or False?
47. When tightening hose or tube fittings, always ________ the fitting body while tightening the nut.
48. Tighten the ________ end of the hose last.
49. The word DRYSEAL refers to a special pipe thread sealer. [✓ True] or False?
50. Study the drawing of a theoretical tube installation on the following page. All fittings are missing. Can you name the correct fitting for each connection?

A list is provided. Some are needed, some are not. Write down the number of each missing fitting and directly opposite it, write the name of the fitting you have chosen to use.


ALL THREADS SHOWN ARE PIPE
1
2
3
4
5
6
7
8
9
PIPE NIPPLE
10
11
12
13

Male Run Tee.

Female 45 deg. Elbow.

Female Run Tee.

Distribution Block.

Male 45 deg. Elbow.

Male Connector.

Female Connector.

Union Cross.

Female Branch Tee.

Bulkhead Union.

Straight Union.

Male Double 90 deg. Elbow.

Female Double 90 deg. Elbow.

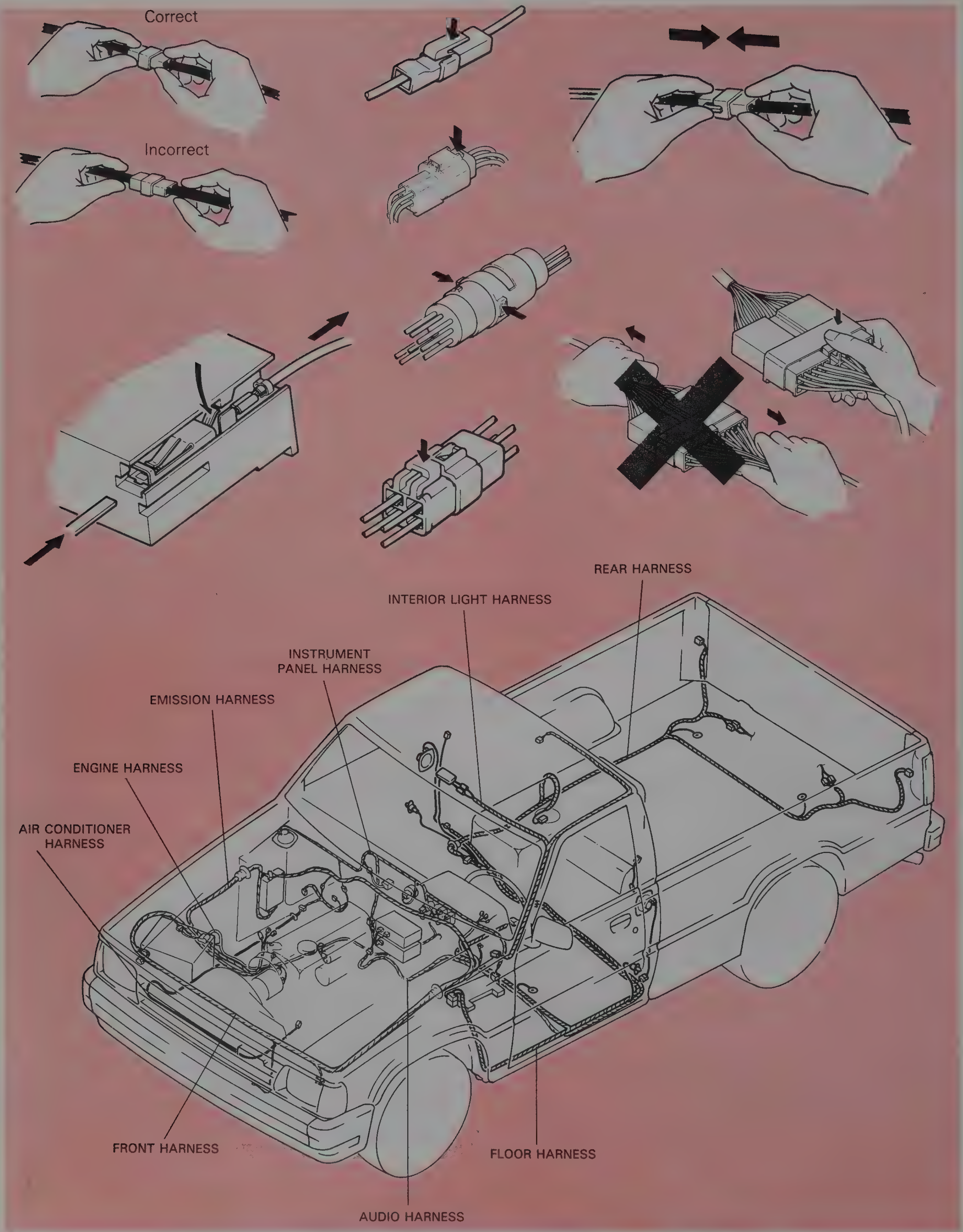
45 deg. Street Elbow.

Pipe Coupling.

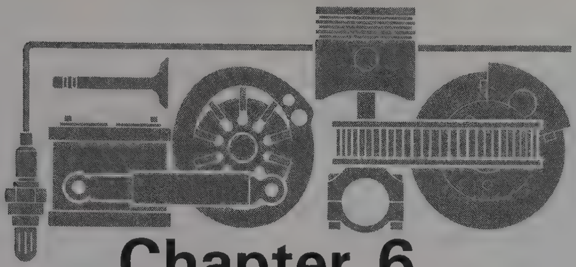
Male 90 deg. Elbow.

Male Branch Tee.

Union Tee.


Correct
Incorrect
REAR HARNESS
INTERIOR LIGHT HARNESS
INSTRUMENT PANEL HARNESS
EMISSION HARNESS
ENGINE HARNESS
AIR CONDITIONER HARNESS
FRONT HARNESS
FLOOR HARNESS
AUDIO HARNESS

Wiring harnesses are used in many places throughout the vehicle's structure. Correct and incorrect techniques for disconnecting various types of wiring harness connectors are shown. (Chrysler and Mazda)



Chapter 6

WIRE AND WIRING

After studying this chapter, you will be able to:
- ☐ Identify different types of automotive wiring.
- ☐ Select the correct type of wiring for the job.
- ☐ Make basic wiring repairs.
- ☐ Read wiring diagrams.
- ☐ Perform basic circuit tests.

New wiring, properly installed, is relatively trouble free. As the car ages, the wires tend to deteriorate from exposure to heat, oil, gas, fumes, acid, and vibration. Vehicles damaged by collision or fire often require extensive rewiring. The auto mechanic should become familiar with types of wire, sizes, insulation, connections, and general installation procedures.

PRIMARY WIRE

The primary wiring handles battery voltage - 6, 12, and in some commercial vehicles, 24 volts. It has sufficient insulation to prevent current loss at these voltages. All wiring circuits in the car, with the exception of the ignition high tension circuit, use primary wire. NEVER USE PRIMARY WIRE FOR SPARK PLUG LEADS.

SECONDARY WIRE

Secondary wire is used in the ignition system high tension circuit - coil to distributor, distributor to plugs. It has a heavy layer of insulation to protect against excessive corona (loss of electrons to the surrounding air) which could impart sufficient current into an adjacent wire to cause it to fire a plug. This action is known as cross-firing. Even with good insulation it is important to arrange spark plug leads so that leads to cylinders that fire consecutively are separated. Fig. 6-1 shows the relative difference in the amount of insulation on primary and secondary wires.

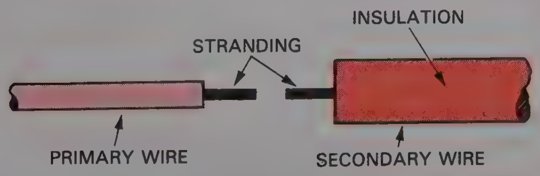


Fig. 6-1. More insulation is required on secondary wires.

STRANDING MATERIAL

Soft copper is widely used for wire stranding. It is an excellent conductor, bends easily, and solders readily. Aluminum also is used to some extent. Copper, stainless steel, carbon impregnated thread, and elastomer type conductors are used for secondary wire stranding. The carbon impregnated thread and elastomer type (Duoprene G, for example) impart a controlled resistance (about 10,000 to 20,000 ohms per foot) in the secondary circuit to reduce radio interference. WHEN WORKING ON THE IGNITION SYSTEM, HANDLE RESISTANCE TYPE HIGH TENSION WIRES CAREFULLY. SHARP BENDING AND JERKING CAN SEPARATE THE CONDUCTOR, THUS RUINING THE WIRE. WHEN REMOVING OR INSTALLING SUCH LEADS, GRIP THE INSULATION BOOT - NOT THE WIRE!

Resistance type wires may be identified by such letters as IRS and TVRS.

Automotive wiring uses stranded (conductor made up of a number of small wires twisted together) conductor.

WIRE SIZE

Each conductor size (do not count thickness of insulation) is assigned a number: the larger the number, the smaller the wire. The American or Brown and Sharpe wire gauge is the commonly used standard for wire size.

To find the gauge of a solid wire, simply measure it with a micrometer. Then locate the answer, or nearest one, on a wire gauge chart. Moving across to the wire gauge column, determine the correct wire gauge.

To find the gauge of a stranded conductor, count the number of strands. With a micrometer, measure the diameter of ONE strand. Square this answer and multiply by the number of strands. This will give you the cross sectional area of the conductor in CIRCULAR MILS. Locate this (or the nearest one) number on the chart. Directly across, under the wire gauge column, determine the gauge. Special steel gauges are also available for quickly checking wire gauge. Fig. 6-2 shows a portion of an AWG (American Wire Gauge) chart. Fig. 6-3 shows a metric wire size conversion chart.

American Wire Gauge	Wire Diameter In Inches	Cross Sectional Area In Circular Mils
0000	.4600	211600
000	.40964	167800
00	.3648	133100
0	.32486	105500
1	.2893	83690
2	.25763	66370
3	.22942	52640
4	.20431	41740
5	.18194	33102
6	.16202	26250
8	.12849	16510
10	.10189	10380
12	.080808	6530
14	.064084	4107
16	.05082	2583
18	.040303	1624
20	.031961	1022
22	.025347	642.4
24	.0201	404.0
26	.01594	254.1
28	.012641	159.8
30	.010025	100.5

Fig. 6-2. American Wire Gauge Chart. (Not all sizes are shown).

Wire Size Conversion Table

Metric Size mm²	AWG Size	Metric Size mm²	AWG Size
0.22	24	5.0	10
0.5	20	8.0	8
0.8	18	13.0	6
1.0	16	19.0	4
2.0	14	32.0	2
3.0	12	52.0	0

Fig. 6-3. Note relationship between AWG and metric size wire. (Chevrolet)

INSULATION

Plastic of various kinds is used for automotive wire insulation. Rubber is sometimes used. Plastic is highly resistant to heat, cold, fumes, and aging. It strips (peels off) easily and offers excellent dielectric (nonconducting) properties. Silicone secondary wire insulation is very heat resistant.

TERMINAL TYPES

Wire end terminals (connecting devices) are offered in various shapes and sizes. In general, primary terminals may be classified as spade, lug, flag, roll, slide, blade, ring, and bullet types. They may either be solderable or solderless. They are generally made of tinplated copper. See Fig. 6-4.

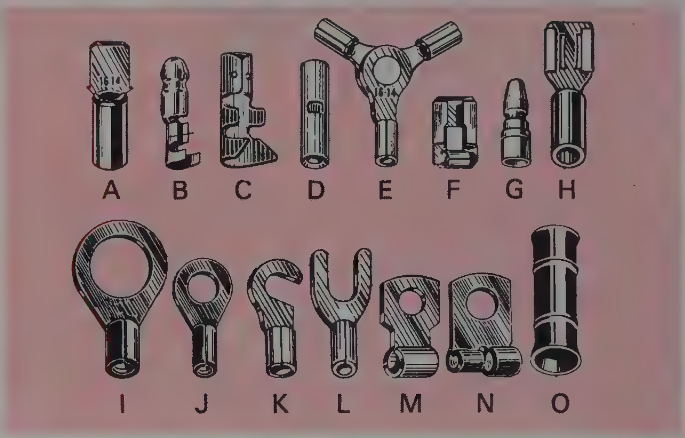


Fig. 6-4. Common primary wire terminal types. A—Male slide. B—Bullet or snap-in. C—Female snap-on. D—Butt connector (must be crimped). E—Three-way connector. F—Female slide. G—Bullet. H—Female slide. I—Lug. J—Ring. K—Hook. L—Spade. M—Roll. N—Flag. O—Female bullet connector. (Belden Mfg. Co.)

BATTERY CABLE TERMINALS

New battery cables (with factory installed terminals) are generally used to replace a used cable with a corroded, useless terminal. However, it is occasionally desirable to replace only the terminal. A number of different types are available, Fig. 6-5.

Terminals on battery cables should be SOLDERED ON. This will insure a good connection with very little voltage drop (lowering of line voltage due to loose, dirty, or corroded connections). It will also protect against the entry of battery acid and fumes. Soldering will be covered later in this chapter.

TERMINAL BLOCKS

The terminal block is used to supply current to several circuits from one feeder source. The hot wire

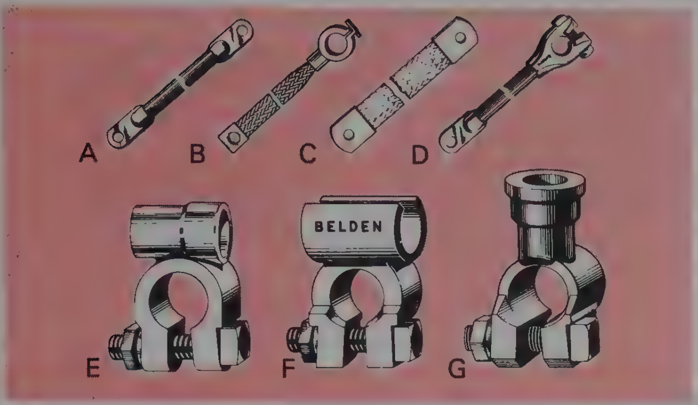

A
B
C
D
BELDEN
E
F
G

Fig. 6-5. Typical battery cables and terminals. A—Solenoid-to-starter cable. B—Battery ground cable. C—Engine ground strap. D—Battery-to-solenoid cable. E—Closed barrel terminal. F—Open-split barrel terminal. G—Closed barrel terminal. Note that ground cables have no insulation and are of a woven construction. Regular insulated battery cable is also used for ground cables.

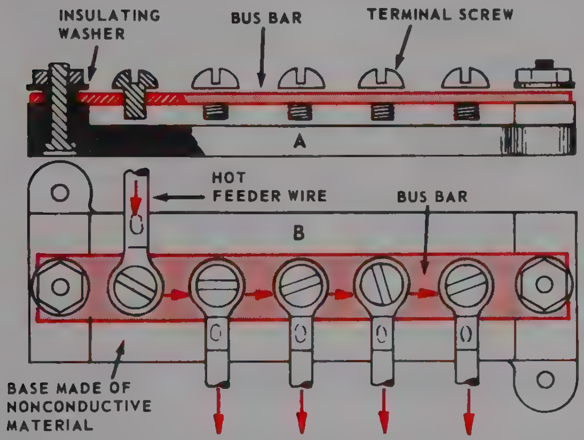

INSULATING WASHER
BUS BAR
TERMINAL SCREW
A
HOT FEEDER WIRE
BUS BAR
B
BASE MADE OF NONCONDUCTIVE MATERIAL

Fig. 6-6. One type of terminal block. Notice how one hot wire is attached to bus bar, thus supplying current to other leads.

(wire connected to source of electricity) is attached to one terminal. This terminal is connected to all others by a bus bar (metal plate), Fig. 6-6.

JUNCTION BLOCK

The junction block serves as a common connection point for a number of wires. It may be of the terminal screw or the plug-in type. Unlike the terminal block, the junction block merely connects one wire to a corresponding wire on the other side. There is no common bus bar, Fig. 6-7.

FUSE BLOCK

The fuse block is similar to the junction block except that a fuse is inserted between the connecting points. This protects each circuit against electrical overloads, and groups a number of fuses in one location. A simple fuse block is shown in Fig. 6-8. Fig. 6-9 illustrates a fuse block utilizing the compact miniature fuse.

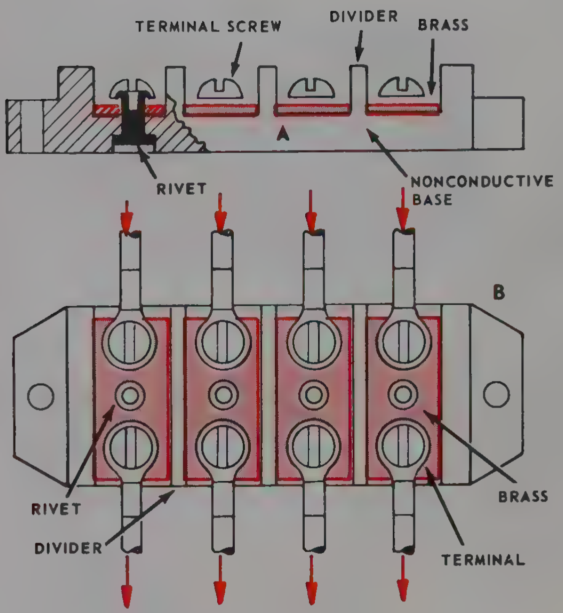

TERMINAL SCREW
DIVIDER
BRASS
A
RIVET
NONCONDUCTIVE BASE
B
RIVET
DIVIDER
BRASS
TERMINAL

Fig. 6-7. Screw type junction block.

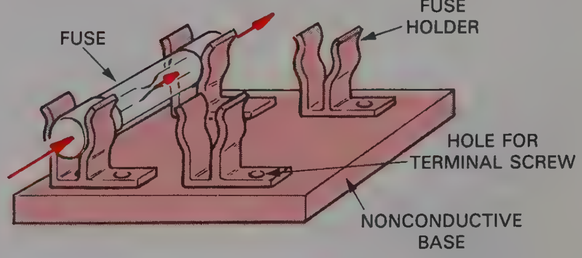

FUSE
FUSE HOLDER
HOLE FOR TERMINAL SCREW
NONCONDUCTIVE BASE

Fig. 6-8. Fuse block. Fuse blocks often contain a number of fuses.

WIRING HARNESS

In an automobile, various sections of wiring are made up in units with common wires (located in same area) either pulled through loom (soft woven insulation tube) or taped or tied together. This speeds installation, makes a neat package, and provides proper securing with a greatly reduced number of clamps or clips. Fig. 6-10 shows a typical wiring harness.

COLOR CODING

All automotive wiring is color coded (each circuit is given a specific color or number of colors) to assist the mechanic in tracing various circuits. Manufacturers publish wiring diagrams that show all wires and color or colors of each.

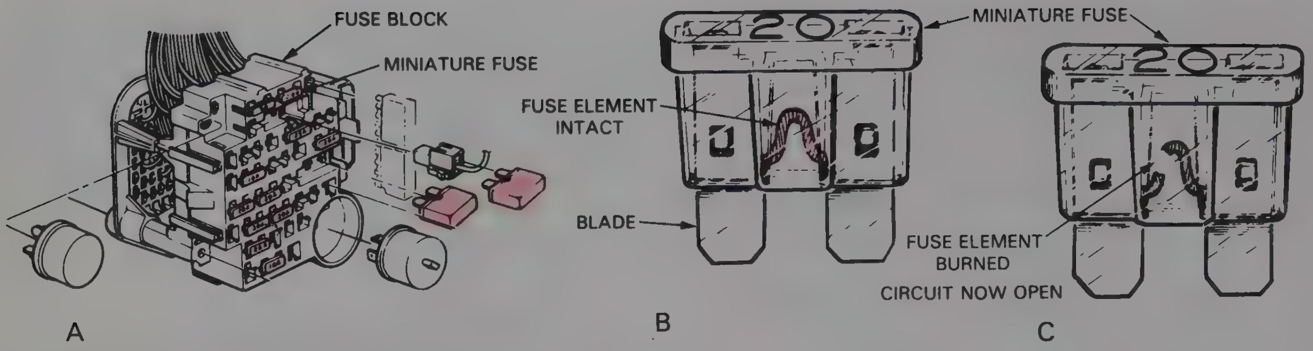

FUSE BLOCK
MINIATURE FUSE
A
FUSE ELEMENT INTACT
BLADE
B
MINIATURE FUSE
FUSE ELEMENT BURNED
CIRCUIT NOW OPEN
C
20
20

Fig. 6-9. A—Fuse block incorporating a number of miniaturized fuses. B—"Good" miniaturized fuse. Note that element is sound. Current flows from one blade, through element, and out other blade. C—Fuse is "Bad." Element is burned in half, thus opening circuit. (Pontiac-Buick)

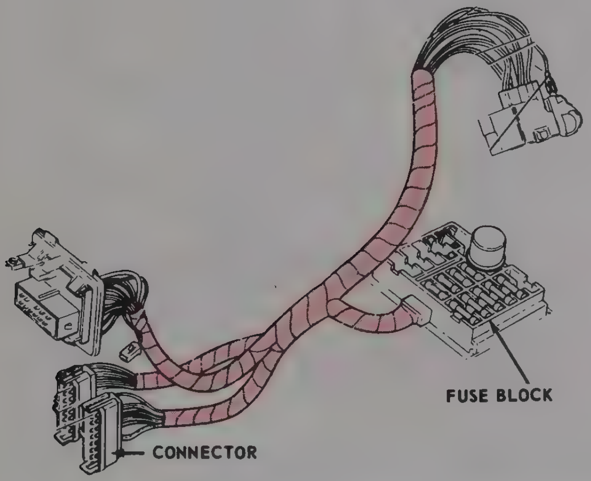

FUSE BLOCK
CONNECTOR

Fig. 6-10. One type of automotive wiring harness. Note fuse block and use of plug-in type connectors.

After aging or exposure to dirt and oil, some wires are difficult to identify by color. In this case, trace the wire back to where it enters the harness. Then, cut away a small portion of the harness covering. This will expose a clean portion of the wire so the color may be determined.

WIRING DIAGRAMS

A wiring diagram is a drawing showing electrical units and the wires connecting them. Such a diagram is helpful when working on the wiring system. As mentioned, wiring diagrams are available in various shop manuals and in some automotive reference type books. Use them! Fig. 6-11 shows a typical wiring diagram for a specific unit. The auto electrical system is becoming more complicated each year. Many manufacturers break down the circuits into separate diagrams, show how to use them, and provide an overall diagram of the entire electrical system, Fig. 6-12.

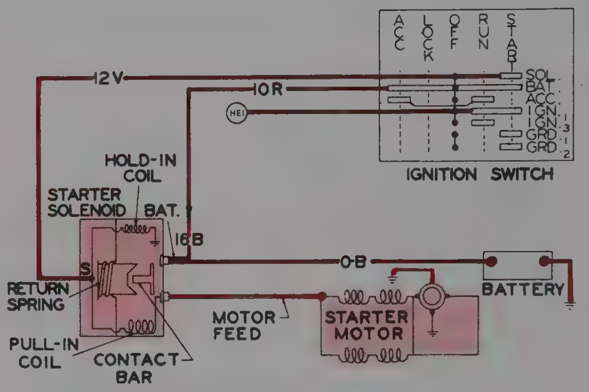

ACC
LOCK
OFF
RUN
START
SOL.
BAT.
ACC.
IGN. 1
IGN. 3
GRD. 3
GRD. 2
IGNITION SWITCH
12V
10R
HEI
HOLD-IN COIL
STARTER SOLENOID
BAT.
16B
S
0-B
BATTERY
RETURN SPRING
MOTOR FEED
STARTER MOTOR
PULL-IN COIL
CONTACT BAR

Fig. 6-11. Wiring diagram for starter system. (GMC)

ELECTRICAL WIRING SYMBOLS

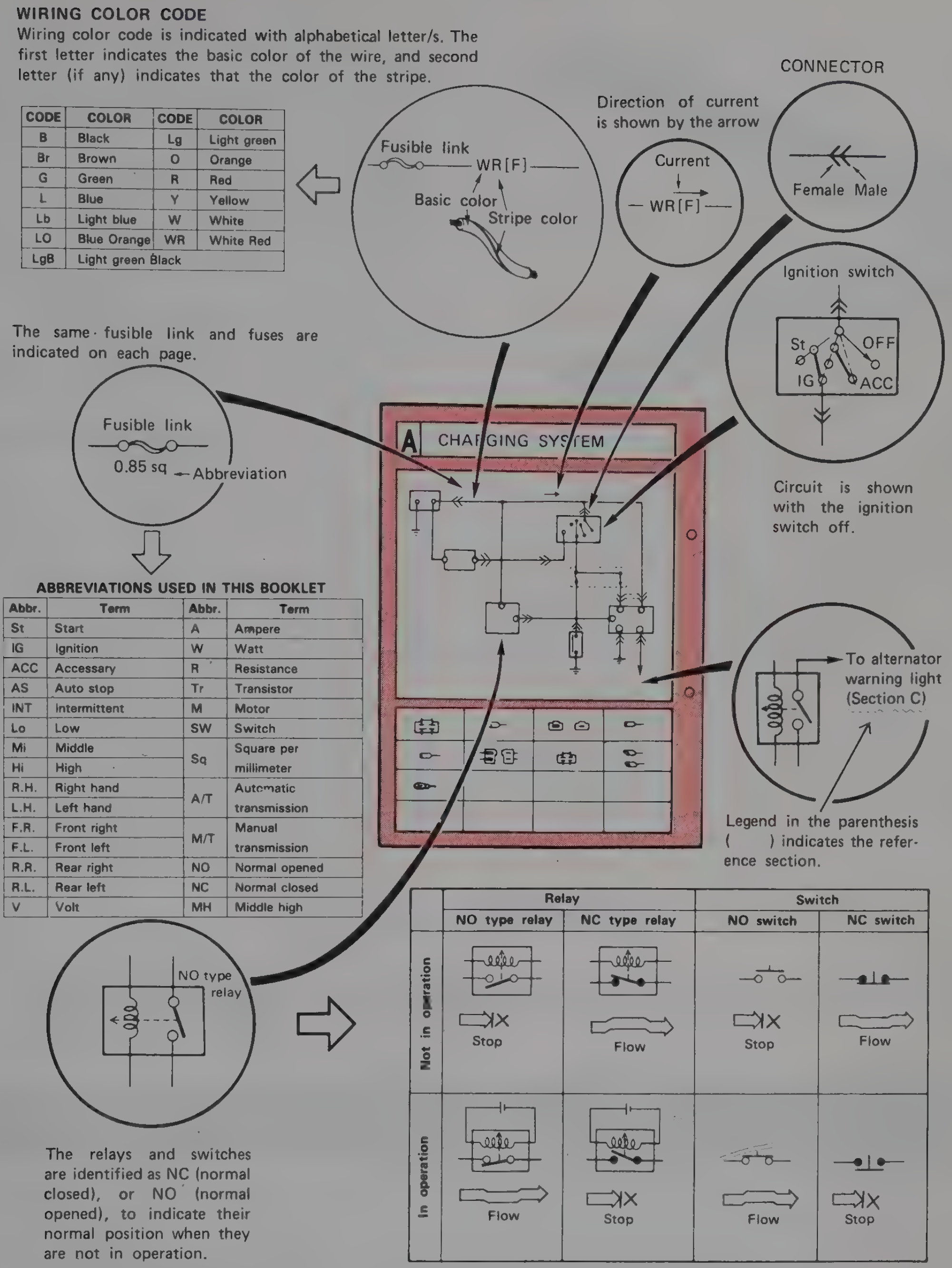
There is a wide variation in the use of automotive electrical symbols. Some companies use their own drawings for some units and standard symbols for others. The units basic internal circuit is sometimes shown. In other diagrams, symbols are used for all units. Fig. 6-13 illustrates a number of typical symbols widely used in automotive electrical diagrams.

SELECTING CORRECT WIRE GAUGE

Line voltage, electrical load, and wire length are the three important factors in determining correct wire gauge or size.

Keep in mind that as wire length INCREASES, resistance (with resultant voltage drop) INCREASES. Resistance causes the conductor to heat. Excessive resistance can heat it to the point where the insulation will melt and burn.

As wire size INCREASES, resistance DECREASES. A simple rule then would be; to prevent high resistance and voltage drop, wire size must be increased as length is increased. It is obvious then, that with a given voltage and load, a wire 20 ft. long must be of a larger gauge


Fusible link
WR[F]
Basic color
Stripe color
CONNECTOR
Female Male
Direction of current is shown by the arrow
Current
WR[F]
Ignition switch
St
OFF
IG
ACC
Circuit is shown with the ignition switch off.
The same fusible link and fuses are indicated on each page.
Fusible link
0.85 sq
Abbreviation
A
CHARGING SYSTEM
To alternator warning light (Section C)
Legend in the parenthesis ( ) indicates the reference section.
NO type relay
The relays and switches are identified as NC (normal closed), or NO (normal opened), to indicate their normal position when they are not in operation.

WIRING COLOR CODE

Wiring color code is indicated with alphabetical letter/s. The first letter indicates the basic color of the wire, and second letter (if any) indicates that the color of the stripe.

CODE	COLOR	CODE	COLOR
B	Black	Lg	Light green
Br	Brown	O	Orange
G	Green	R	Red
L	Blue	Y	Yellow
Lb	Light blue	W	White
LO	Blue Orange	WR	White Red
LgB	Light green Black		

ABBREVIATIONS USED IN THIS BOOKLET

Abbr.	Term	Abbr.	Term
St	Start	A	Ampere
IG	Ignition	W	Watt
ACC	Accessary	R	Resistance
AS	Auto stop	Tr	Transistor
INT	Intermittent	M	Motor
Lo	Low	SW	Switch
Mi	Middle	Sq	Square per millimeter
Hi	High		
R.H.	Right hand	A/T	Automatic transmission
L.H.	Left hand		
F.R.	Front right	M/T	Manual transmission
F.L.	Front left		
R.R.	Rear right	NO	Normal opened
R.L.	Rear left	NC	Normal closed
V	Volt	MH	Middle high

	Relay		Switch	
	NO type relay	NC type relay	NO switch	NC switch
Not in operation	Stop	Flow	Stop	Flow
In operation	Flow	Stop	Flow	Stop

Fig. 6-12. Note how each area from electrical service manual is explained. Failure to use and understand these diagrams can cause considerable electrical damage. (Mazda)

than one 2 ft. long.

The electrical load imposed on a wire is merely the sum of the individual loads of each unit serviced by that wire. Common automotive system voltage is now 12 volts. Some commercial vehicles use 24V. Most cars produced a number of years ago used 6V systems.

Most wire manufacturers furnish charts, similar to that shown in Fig. 6-14. They assist the mechanic in proper gauge selection. To use the chart shown, determine the total length of the wire needed. The wire lengths shown in the chart are for a single wire ground return (no wire needed from unit, frame or metal parts of car act as a return ground wire). If installing a two-wire circuit (one wire to unit and another from unit to ground), count the length of both wires.

Next compute the total electrical load to which the wire will be subjected. Be certain to figure the load of ALL units concerned. If the load will fluctuate, use the peak load figure. The load may be figured in AMPERES, WATTAGE, or CANDELA (Candela is international term for candlepower.).

When the load is determined, look on the chart under the correct voltage column for the nearest listed load. Move across the chart horizontally until under the

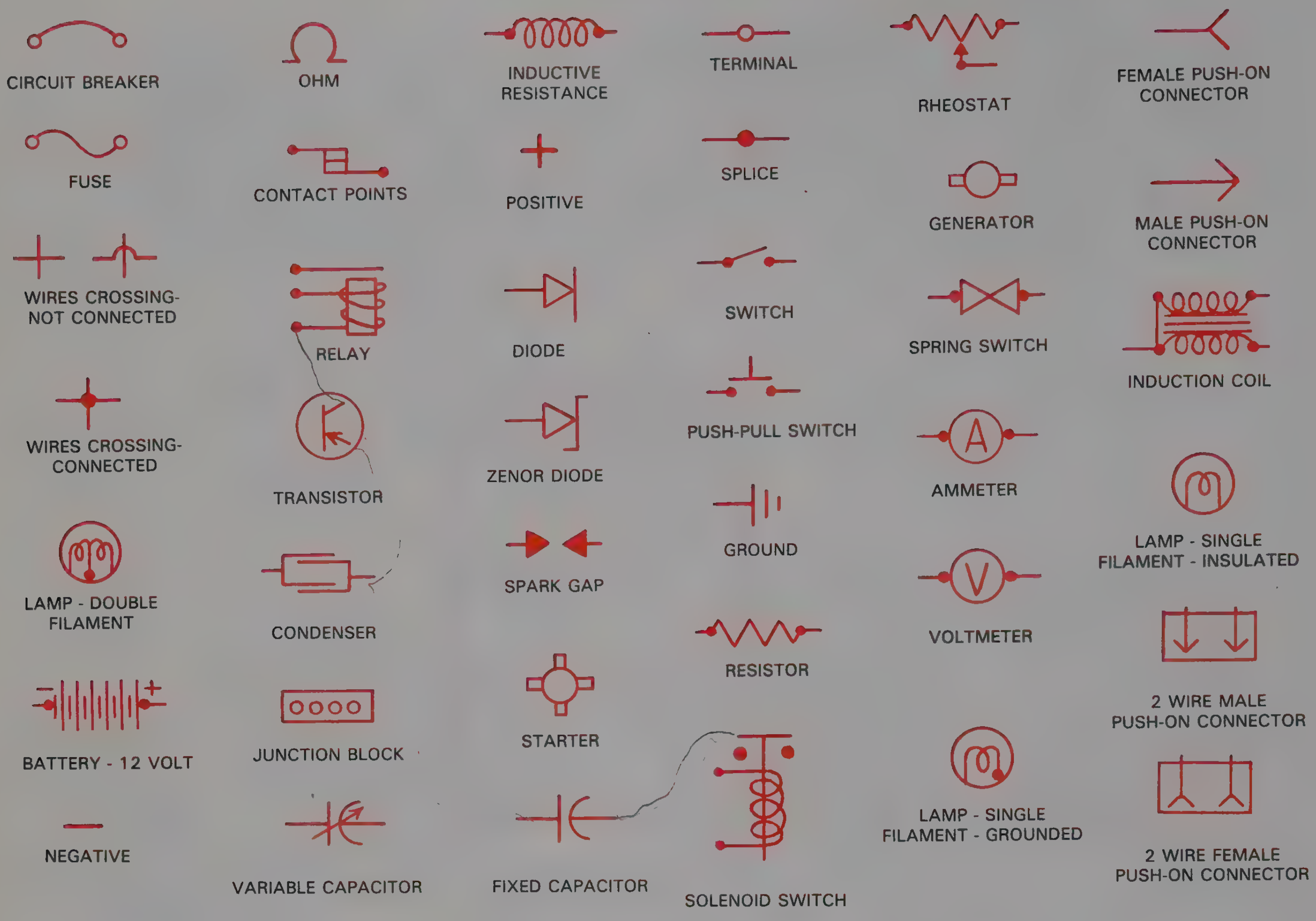

CIRCUIT BREAKER
OHM
INDUCTIVE RESISTANCE
TERMINAL
RHEOSTAT
FEMALE PUSH-ON CONNECTOR
FUSE
CONTACT POINTS
POSITIVE
SPLICE
GENERATOR
MALE PUSH-ON CONNECTOR
WIRES CROSSING-NOT CONNECTED
RELAY
DIODE
SWITCH
SPRING SWITCH
INDUCTION COIL
WIRES CROSSING-CONNECTED
TRANSISTOR
ZENOR DIODE
PUSH-PULL SWITCH
AMMETER
LAMP - DOUBLE FILAMENT
GROUND
LAMP - SINGLE FILAMENT - INSULATED
CONDENSER
SPARK GAP
VOLTMETER
RESISTOR
2 WIRE MALE PUSH-ON CONNECTOR
BATTERY - 12 VOLT
JUNCTION BLOCK
STARTER
LAMP - SINGLE FILAMENT - GROUNDED
NEGATIVE
VARIABLE CAPACITOR
FIXED CAPACITOR
SOLENOID SWITCH
2 WIRE FEMALE PUSH-ON CONNECTOR

Fig. 6-13. Electrical symbols commonly used in automotive wiring diagrams.

Total Approx. Circuit Amperes		Total Circuit Watts		Total Candle Power		Wire Gauge (For Length in Feet)											
6V	12V	6V	12V	6V	12V	3′	5′	7′	10′	15′	20′	25′	30′	40′	50	75	100
0.5	1.0	3	6	3	6	18	18	18	18	18	18	18	18	18	18	18	18
0.75	1.5			5	10	18	18	18	18	18	18	18	18	18	18	18	18
1.0	2	6	12	8	16	18	18	18	18	18	18	18	18	18	18	16	16
1.5	3			12	24	18	18	18	18	18	18	18	18	18	18	14	14
2.0	4	12	24	15	30	18	18	18	18	18	18	18	18	16	16	12	12
2.5	5			20	40	18	18	18	18	18	18	18	18	16	14	12	12
3.0	6	18	36	25	50	18	18	18	18	18	18	16	16	16	14	12	10
3.5	7			30	60	18	18	18	18	18	18	16	16	14	14	10	10
4.0	8	24	48	35	70	18	18	18	18	18	16	16	16	14	12	10	10
5.0	10	30	60	40	80	18	18	18	18	16	16	16	14	12	12	10	10
5.5	11			45	90	18	18	18	18	16	16	14	14	12	12	10	8
6.0	12	36	72	50	100	18	18	18	18	16	16	14	14	12	12	10	8
7.5	15			60	120	18	18	18	18	14	14	12	12	12	10	8	8
9.0	18	54	108	70	140	18	18	16	16	14	14	12	12	10	10	8	8
10	20	60	120	80	160	18	18	16	16	14	12	10	10	10	10	8	6
11	22	66	132	90	180	18	18	16	16	12	12	10	10	10	8	6	6
12	24	72	144	100	200	*18	18	16	16	12	12	10	10	10	8	6	6
15	30					18	16	16	14	10	10	10	10	10	6	4	4
20	40					18	16	14	12	10	10	8	8	6	6	4	2
25	50					16	14	12	12	10	10	8	8	6	6	2	2
50	100					12	12	10	10	6	6	4	4	4	2	1	0
75	150					10	10	8	8	4	4	2	2	2	1	00	00
100	200					10	8	8	6	4	4	2	2	1	0	4/0	4/0

* 18 AWG indicated above this line could be 20 AWG electrically—18 AWG is recommended for mechanical strength.

Fig. 6-14. Wire gauge selection chart. Wire lengths shown are for a single wire ground return. (Belden Mfg. Co.)

nearest listed footage. This will give you the recommended gauge.

For example, say you have a 12V system, a computed electrical load of 20 amperes, and a wire length of 15 feet. Looking on the chart, you will find the recommended gauge to be No. 14. For the same load and length but with a 6V system, the recommended gauge is 10. You will notice that a 12V system uses a smaller gauge wire than a 6V system.

Using a larger gauge than necessary will cause no particular harm unless the wire being replaced MUST produced a specific resistance in the circuit, Fig. 6-14.

SELECTING PROPER TERMINALS

After the wire gauge is determined, select the proper size and type terminal. The terminal must be suitable for the unit connecting post or prongs. It must have sufficient current carrying capacity and should be heavy enough to prevent breakage through normal wire flexing and vibration. Fig. 6-15 shows some common errors in terminal selection.

Arrange terminals so they have clearance from metal parts that could ground or short them out. On critical applications or where heavy vibration is present, use a terminal such as the ring type that completely encircles the post. If it loosens, the wire will not fall off.

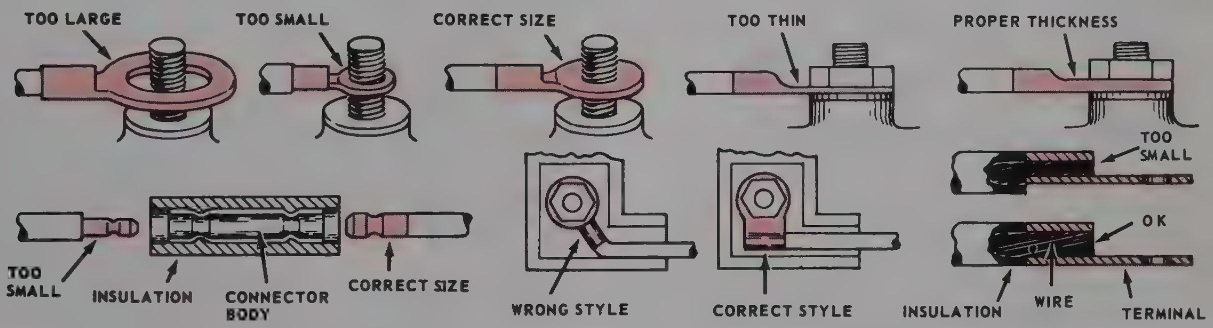


Fig. 6-15. Some common errors in terminal selection.

ATTACHING TERMINALS

Terminals may be either soldered or crimped in place. Crimping is fast and forms a good connection. Soldering, if properly done, forms an excellent connection and, in some cases, may be desired. It is possible to both solder and crimp a connection. Solder forms an electrical path and is not depended on for strength.

Aluminum wire requires crimped terminals.

CRIMPING TERMINALS

A crimping tool is shown in Fig. 6-16. It will cut and strip the wire as well as form a proper crimp.

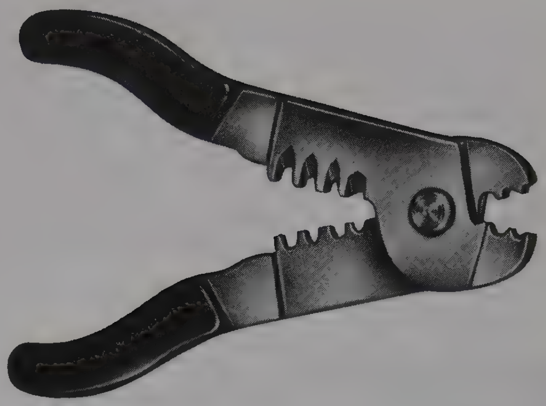


Fig. 6-16. Crimping tool. (Cole-Hersee Co.)

The first step is to strip the insulation back for a distance equal to the length of the terminal barrel. The wire is then shoved into the barrel. While being held in, the crimping tool is placed over the spot to be crimped. Be sure to use the proper crimping edge. The handles are squeezed together and the terminal barrel firmly crimped to the wire. Follow the tool manufacturer's instructions. Use the correct barrel size for the wire used. NEVER CRIMP A WIRE WITH THE CUTTING EDGE OF A PAIR OF PLIERS. This would crimp the barrel but weaken it, Fig. 6-17.

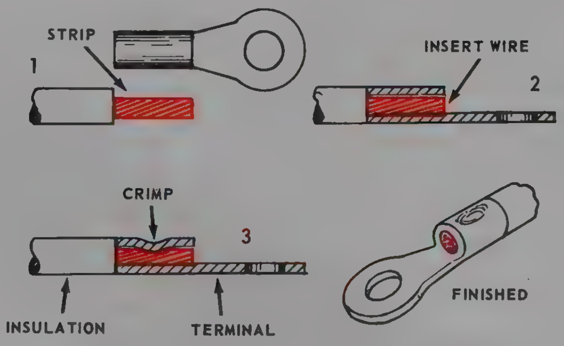


Fig. 6-17. Crimping a terminal.

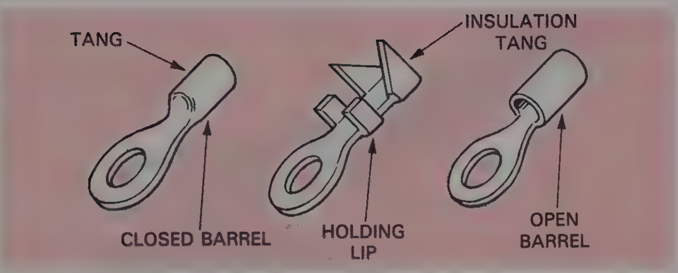


Fig. 6-18. Terminal tangs.

SOLDERING TERMINALS

Terminals do not have to be especially made for soldering but the lip-type terminal tang lends itself to soldering better than the closed or open barrel tang, Fig. 6-18.

To solder the lip type, strip the wire back as shown in A, Fig. 6-19. Insert the wire as shown in B. Crimp the wire holding lips, one after the other, tightly over the wire. Then, carefully fold the insulation tang around the insulated portion of the wire, as in C and D.

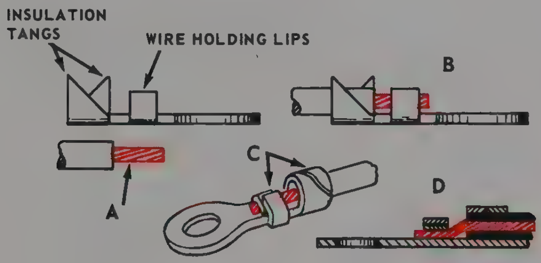


Fig. 6-19. Soldering lip type terminal.

Using ROSIN CORE (NOT ACID CORE) wire solder, place a drop of solder on the holding lips. Hold the iron in contact with the drop until it flows into the lips and wire. Do not hold the iron in contact with the terminal any longer than necessary. This tends to melt the insulation.

When soldering the open barrel type, strip as for crimping. Tin the exposed wire end (coat with a thin layer of solder). Insert in the barrel. While holding the exposed end upright, heat the socket with the iron. While heating, keep wire solder against socket end. When the solder melts, flow it into the barrel. Make certain a sufficient amount enters. Hold the iron in place for a few seconds longer to allow the solder to bond to both the barrel and wire. The barrel may also be crimped if so desired. Crimp before soldering! See Fig. 6-20.

The closed barrel type should be heated and a small amount of solder flowed into the hole. While keeping the barrel hot, press the tinned wire into the hole. Hold the iron in place for several seconds to insure bonding.

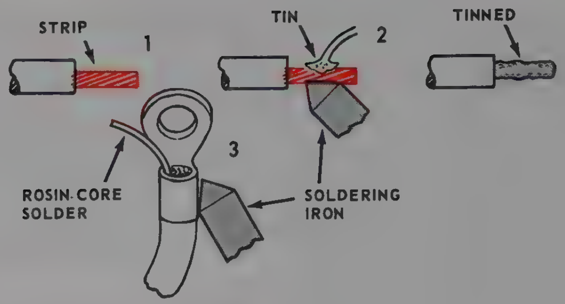


Fig. 6-20. Soldering barrel type terminal tang.

For more complete instructions on the use of the soldering iron, see the chapter on soldering, brazing, and welding.

When an insulator boot is to cover the terminal tang or when attaching slide type terminals that will be snapped back into a housing, always slide the boot, housing, etc., on the wire before soldering.

SOLDERING BATTERY TERMINALS

The common practice is to replace the entire battery cable when the terminals are no longer fit for use. However, if it becomes necessary to install a new terminal, use the following procedure.

Cut the cable back far enough to remove the corroded section. Peel the insulation (ground cables often have none) back equal to the depth of the terminal barrel. Place the terminal in a vise, open barrel end up.

Using an acetylene torch (low heat, flame rich in acetylene), heat the stripped cable end. Using rosin core wire solder, flow solder freely into the wire until all strands have been tinned. It may help to rub on a little rosin type soldering paste to assist with tinning.

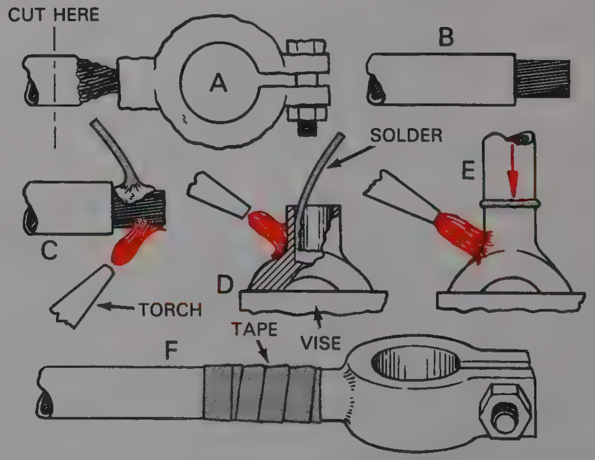


Fig. 6-21. Soldering a battery terminal. A—Cut off corroded section. B—Strip. C—Tin. D—Tin barrel and add solder. E—Insert cable. F—Tape.

Place a dab of soldering paste in the terminal barrel. Heat with the torch (keep flame on outside of terminal). When hot, flow solder into the barrel until about one-quarter full. While retaining the heat with the torch, force the tinned cable down into the socket. When it slips in the full depth, solder will flow up and over the lip of the barrel. Hold the heat, moving the flame around the terminal outside, for a few seconds longer to allow the heavy cable to heat up and bond firmly to the barrel. Remove heat and hold cable steady until solder sets. Cool under a cold tap. Dry terminal and cable insulation. Then, apply plastic tape as shown in Fig. 6-21. For open barrel terminals, tin both cable and inside of barrel heavily. While heating, slide together as above. Do not try to solder battery terminals with a soldering iron - it will not produce sufficient heat.

ATTACHING SPARK PLUG WIRE TERMINALS

Fig. 6-22 shows various spark plug wire terminals. The boots protect against moisture and dirt that can cause flashover (spark jumping to ground along outside of plug porcelain top). Ready-made sets often bond the boots to both the terminal and wire for added protection against flashover.

When selecting plug end terminals, choose a shape that will snap on the plug without bending the wire sharply. The same applies to distributor terminals, Fig. 6-23.

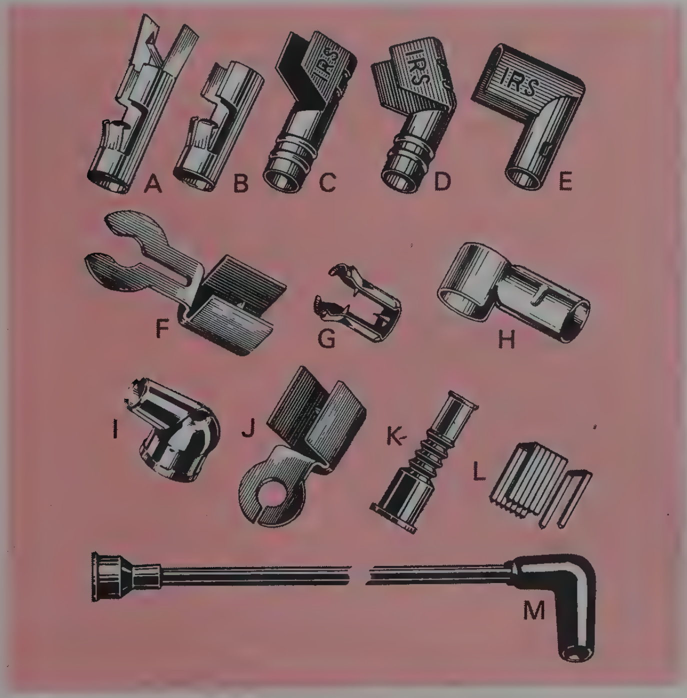


Fig. 6-22. Spark plug wire terminals and boots. A, B, G—Distributor end terminals. C, D, E, F, G, H, J—Spark plug end terminals. I—Right angle distributor end boot. K—Flexible plug end boot. L—Staples for use with resistance type wire. M— Replacement plug wire with boots bonded to wire.

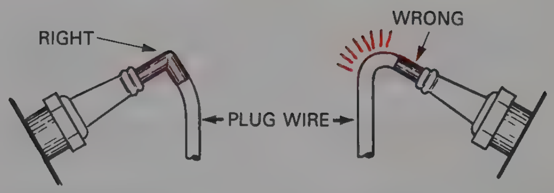


Fig. 6-23. Choose a terminal shape that will allow the wire to be attached without sharp bending. The wire on right will soon fail.

Although some plug end terminals have a sharp barb that is designed to penetrate the insulation and contact the wire (as well as providing holding power), it is good practice to strip the insulation enough to allow the wire to be bent around and laid against the outside of the insulation. This insures a good electrical contact. See A, Fig. 6-24. Some distributor end terminals, such as in B, Fig. 6-24, have the barbs both at the sides and end. Wire stripping is not necessary if the barb is carefully inserted into the wire end. When attaching terminals to resistance type plug wires, always use staples. The staple is pushed into the wire, thus insuring a large contact area with the special conductor, C, Fig. 6-24.

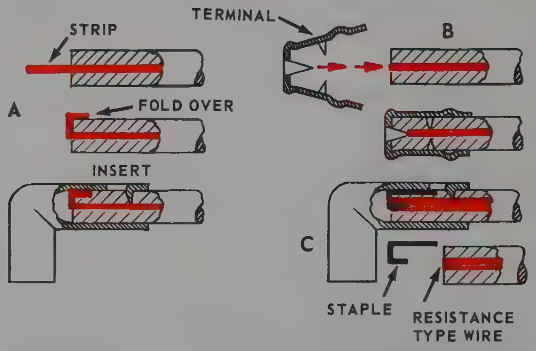


Fig. 6-24. Attaching secondary wire terminals. A—Attaching a plug end terminal to a regular (non-resistance) spark plug wire. B—Attaching a distributor end terminal. C—Using a staple when attaching a terminal to resistance type wire.

JOINING WIRE ENDS

In addition to the terminal, fuse, and junction block, wires may be connected by soldering, crimped butt connectors, and slide or bullet type connectors. If the wire ends are being joined permanently, soldering or butt connectors work very well, Fig. 6-25.

The slide and the bullet type connectors are used where the wires must be separated at some future time. The appropriate slide or bullet terminals are crimped or soldered to the wires. They are then snapped into the connector body and the two halves plugged together, Fig. 6-26.

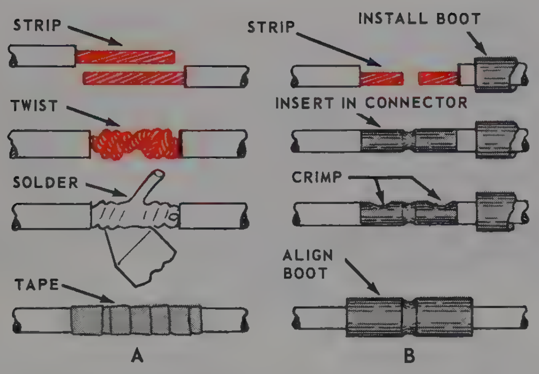


Fig. 6-25. A—Joining wires by soldering. B—Using a crimp type butt connector.

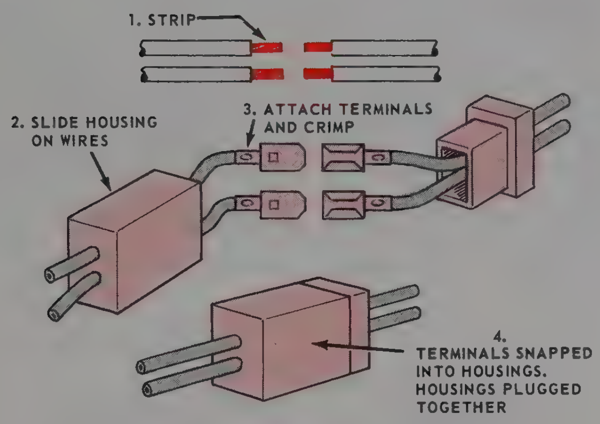

1. STRIP
2. SLIDE HOUSING ON WIRES
3. ATTACH TERMINALS AND CRIMP
4. TERMINALS SNAPPED INTO HOUSINGS. HOUSINGS PLUGGED TOGETHER

Fig. 6-26. Joining wires by using the slide type quick-connect.

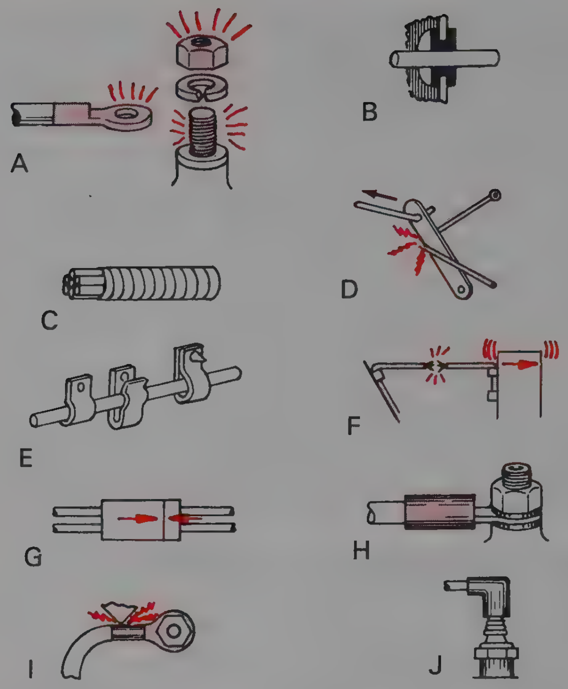


Fig. 6-27. Wiring installation hints. A—Connections must be CLEAN and BRIGHT. B—Use grommets to protect wire passing through thick metal. C—Tape common wires together. D—Avoid moving parts when locating wires. E—Support with suitable clamps. F—Allow some slack when wire runs to a unit that moves. G—Connectors must be pushed together tightly. H—Use boots on terminal tangs and select terminals heavy enough for job. I—Tighten terminals in a position AWAY FROM metal - use boots also. J—Handle resistance plug wires by grasping the boots.

INSTALLING WIRE

Install the wire. Make certain terminals and posts are clean. Connect terminals and tighten securely. Lock washers should be used on screw and post connections. Slip insulator boots, where used, over exposed terminal tang. If of the slide or bullet types, shove together tightly and check to see that the connection is secure.

Keep all wiring away from the exhaust system, oily areas, and moving parts. Secure in place with mounting clips or clamps. Fasten in enough spots to prevent excessive vibration and chafing. Where the wire must pass through a hole in sheet metal, install a rubber grommet, Fig. 6-27. When a wire must pass from the fender well or splash shield to the engine, leave enough slack to allow the engine to rock on the mounts without pulling the wire tight.

When installing spark plug leads, avoid sharp bends. If the wires pass through a metal conduit (tube), the conduit should be securely grounded. Install or remove the plug wires by grasping the insulation boots and not the wire proper. Make sure the terminals snap tightly on the plugs and that the distributor ends are all the way in the housing towers. Follow the manufacturer's instructions in arranging the plug wires. If two leads are together going to cylinders that fire consecutively (one after the other) there is a danger of cross firing—especially as the wires age.

If a number of primary wires travel in a common path, pull them through a loom (woven fiber conduit) or tape them together, Fig. 6-27.

FUSE WHEN NEEDED

When adding accessory units such as spotlights and heaters and no provision was made for them in the original wiring, be certain to place a fuse in the circuit. Fuse as closely as possible to the electrical source. This will reduce the possibility of a short between the fuse and source. A small fuse block may be used or the popular in-line fuse can be installed. Be sure to inform the owner as to the location of the new fuse, Fig. 6-28.

NEVER TAP (CONNECT) INTO THE HEADLIGHT CIRCUIT TO POWER AN ACCESSORY. THIS COULD OVERLOAD THE HEADLIGHT CIRCUIT BREAKER AND CAUSE TROUBLE. If it is desired to have unit inoperative when the ignition

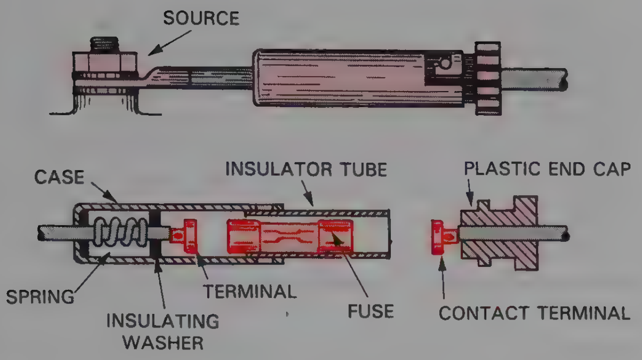


Fig. 6-28. Typical in-line fuse. Fuse as close to the source as practical.

key is OFF, the hot wire must be connected to the key switch circuit.

PRINTED CIRCUIT

Instead of using a maze of wires to connect numerous small and often complex components, printed circuits may be employed.

The printed circuit uses a nonconducting panel upon which the electrical units are affixed. The units are then connected by either thin conductor strips cemented to the panel or by a special electrically conductive material "printed" on in the desired circuit patterns. This permits a great number of individual circuits in a very small area.

The modern auto is making increasingly greater use of the printed circuit in such areas as electronic emission control computers, audio accessories, and dash instrumentation. Fig. 6-29 illustrates the use of a printed circuit in a dash instrument cluster.

CHECKING WIRING

Many problems throughout the car can be traced to faulty wiring. Loose or corroded terminals; frayed, bare, or broken wires; and cracked, oil-soaked, or porous insulation are the most frequent causes.

When troubleshooting a problem, check the wires, fuses, and connections carefully. Remember that wires can separate with no break in the insulation (especially resistance type secondary wire). A terminal may be tight and still be corroded. A fuse link may burn out at one end instead of in the center where it will be visible.

CHECKING FOR CONTINUITY

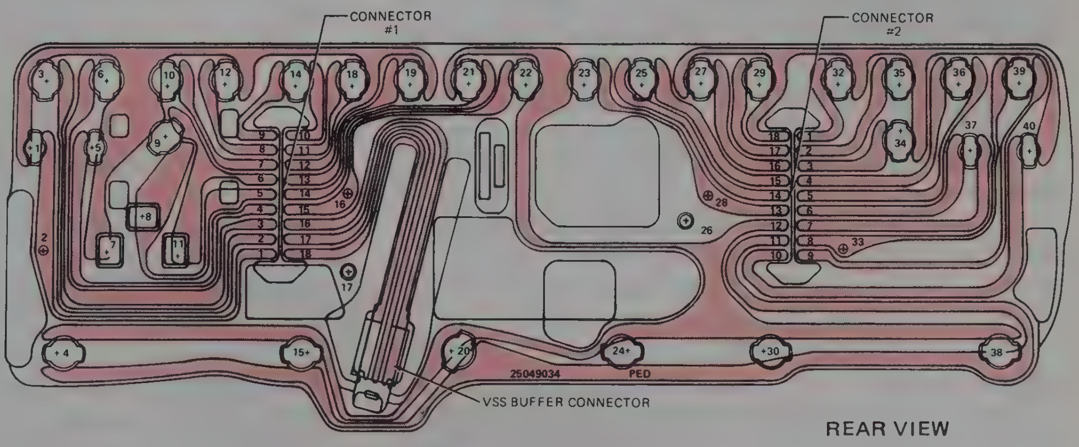
A small test light (battery operated) may be used to test wires for internal breaks. The test point prods can be pushed through the insulation if desired (not on plug wires). Hold one prod against one end of the wire and place the other prod against the other end. If the test lamp burns, the wire is continuous. This simple test light is also handy for checking fuses, shorted field windings, and for tracing wires where there are no color codes. Fig. 6-30 illustrates several checks.

OTHER CHECKS

Wires and connections must occasionally be checked for resistance, voltage drop, short or near-short circuits.

CONNECTOR #1
1. WATER INFUEL T.T.
2. OIL T.T.
3. OIL/CHOKE T.T.
4. WAIT T.T.
5. GROUND
6. FUEL SENDER
7. TEMPERATURE T.T.
8. VOLTAGE T.T.
9. & 10. SPARES
11. CRUISE T.T.
12. IGNITION
13. BRAKE T.T.
14. RIGHT TURN SIGNAL
15. HIGH BEAM T.T.
16. IGNITION—ELECT. SP.
17. SPEED SENSOR
18. GROUND—ELECT. SP.

T.T. = TELLTALE



CONNECTOR #2
4. CAR IS LEVELING T.T.
5. CAR IS LEVELING T.T.
6. LOW WASHER FLUID T.T.
7. LOW WASHER FLUID
8. SECURITY T.T.
9. SECURITY—BATTERY FEED
1, 2, 3, 10 & 17 SPARES
11. ILLUMINATION T.T.
12. GROUND
13. LEFT TURN SIGNAL
14. SEAT BELTS T.T.
15. SEAT BELTS T.T.
16. SERVICE ENGINE SOON T.T.
18. IGNITION

Fig. 6-29. Rear view of a printed circuit instrument panel. (Buick)

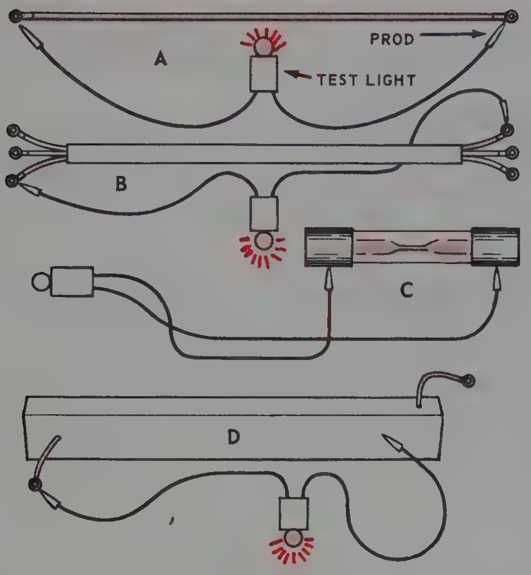


Fig. 6-30. Some wiring checks using a simple test light. A—Prods on ends of wire. Lamp lights indicating wire is continuous. B—Prod held on the end of one wire and the other prod touched to various wire ends. When lamp lights, proper wire end is identified. C—Checking a fuse. Prods in place, lamp does not light. This indicates a faulty fuse. In this case, fuse will be burnt out at end instead of usual narrow center section. D—One prod touched to a wire end and the other prod to ground. If lamp lights, wire is shorted out.

These checks are made with precision instruments: ohmmeter, voltmeter, or ammeter. This will be discussed in the chapters where these tests pertain.

SUMMARY

Primary wire (copper stranding, relatively thin insulation) is used for circuits handling battery voltage. Secondary wire (stainless steel, carbon impregnated thread, and elastomer stranding with very heavy insulation) is used on the ignition high tension circuit. Plastic is widely used for insulation.

All automotive wire uses a stranded (not solid) wire conductor.

The AWG (American Wire Gauge) is determined by the cross sectional area in circular mils. The larger the AWG number, the smaller the size. A micrometer or wire gauge can be used to determine wire size.

Spade, lug, flag, roll, slide, ring, and bullet terminal types are used.

Terminal blocks allow one feeder wire to service a number of other wires. These can be of the screw, bullet, or slide type.

Junction blocks provide a central connecting point for a number of wires.

Fuse blocks give protection against circuit overloads.

A wiring harness contains a number of wires either taped together or pulled through a loom. This keeps common wires neatly arranged and facilitates installation.

Automotive electrical systems are color coded. Use an accurate wiring diagram for troubleshooting or replacing wires.

Line voltage, wire length, and electrical load must be taken into consideration when choosing wire gauge. A wire gauge chart will assist in making the right selection. Remember that undersize wires increase resistance, reduce unit efficiency, and can overheat or burn. On two-wire circuits (one wire for ground) count the length of both wires. A 6V system requires heavier gauge wire than the 12V system.

Be certain that terminals are of the correct style and size. They may be soldered or crimped to the wire. Battery replacement terminals should be soldered. When crimping, use a suitable crimping tool. If soldering, use rosin core wire solder. Always slide insulation boots and housings on the wire before attaching the terminal.

Use staples when installing terminals on resistance type secondary leads. Handle secondary resistance wire carefully.

Wire ends may be joined by soldering, using butt connectors, or by attaching bullet or slide connectors.

When installing wires, keep away from heat, oily areas, and moving parts. Terminals must be clean and tight. Use clips to prevent chafing and excessive vibration.

When adding accessories, fuse the circuit as close to the source as possible. Do not tap into the headlight circuit for an accessory.

Clean, tight connections, with proper size wire and good insulation, are imperative. When troubleshooting, always check connections and insulation. Replace cracked, spongy, or frayed wires.

Many wiring checks can be made with a simple test light.

Printed circuits find some application on the auto.

SUGGESTED ACTIVITIES

1. Using the primary wire size selection chart in this chapter, determine the correct size wire for the following:
   A. Load — 100 candela
      Wire length — 11 feet
      Voltage — 12
      Wire gauge should be __________.
   B. Load — 50 amperes
      Wire length — 20 feet
      Voltage — 12
      Wire gauge should be __________.
   C. Load — 70 watts
      Wire length — 15 feet
      Voltage — 6
      Wire gauge should be __________.
2. Attach several terminals by crimping and soldering.

3. On a damp, dark night, start the engine in a car (especially one several years old that has been parked outside). Without turning on the lights, raise the hood and see if you can detect the corona effect around the plug wires. DO NOT RUN THE CAR IN A CLOSED GARAGE!
4. Inspect the wiring on a late model car. What kinds of terminals are used? Study the wiring harness and see how many kinds of wire clips and clamps you can find.
5. Study the wiring diagram of a car electrical system. Trace several circuits starting at the unit and going back to the source. Note the color coding and use of symbols.

TOOLS ARE IMPORTANT

Remember — to do good work, a mechanic needs a good assortment of tools. To learn, a student needs a good assortment of words. Words are very important "tools" for learning. When YOU come across a new word, LOOK UP THE MEANING and add it to your "TOOL CHEST."

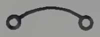
KNOW THESE TERMS

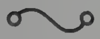
Primary wire, Secondary wire, AWG, Fuse block, Wiring harness, Color coding, Circuit breaker, Filament, Amperes, Watts, Crimped terminal, Rosin core, Acid core, Mini fuse, Printed circuit, Continuity, Voltage drop, Short circuit, Conductor, Fusible link, Diagnostic plug-in, Insulation, Resistance wire, Wiring diagram, Rubber grommet, In-line fuse, Test lamp, Ohmmeter, Voltmeter, Feeder wire.

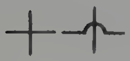
QUIZ - Chapter 6

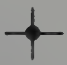
1. Primary wire makes excellent spark plug leads. True or False?
2. The most commonly used insulation material is _______________.
3. Resistance type spark plug wires are used to provide a hotter spark. True or False?
4. Name three materials used for secondary wire stranding.
5. Stranding for primary wire is made of __________.
6. Resistor spark plug cables are easily damaged by sharp bends and jerking. True or False?
7. All primary automotive wire uses a stranded conductor. True or False?
8. The ___________________ is the standard for wire size.
9. The larger the wire number, the larger the wire. True or False?
10. Cross sectional area in square mils determines the wire size. True or False?
11. Name five common primary terminal types.
12. Replacement battery cable terminals should be ____________________.
13. One feeder wire can service several others through the use of a ___________ block.
14. A number of wires can be connected together in a common location by using a __________ block.
15. The _______________ protects a circuit from an overload.
16. A number of common wires, taped together, with leads leaving at various spots, is referred to as a wiring _____________.
17. Automotive wiring is ___________ coded.
18. What is a wiring diagram?
19. The three major considerations in selecting the correct wire gauge for a specific circuit are _____, wire ___________, and electrical ___________.
20. An undersize wire will increase _____________ and will _____________.
21. In computing wire length for a two-wire circuit, both wire lengths should be counted. True or False?
22. No. 16 wire is smaller than No. 18 wire. True or False?
23. _________________ is the international term for candlepower.
24. Wiring for a 12V circuit is of a heavier gauge than that for 6 volt. True or False?
25. As long as a terminal fits the stud or post, it is OK to use. True or False?
26. ___________ terminals to the wire is more widely used than ___________.
27. Use ___________ when attaching terminals to resistance type secondary wire.
28. Copper or stainless steel secondary wire should have a small portion of the insulation stripped and the wire bent up and around the outside of the insulation. True or False?
29. If, when joining wire ends, it is desirable to be able to disconnect them at a future date, a _________ type connector would be a good choice.
30. As long as a connection is tight, it will be a good conductor. True or False?
31. Grommets are used to protect wire passing through thin sheet metal. True or False?
32. When plug leads pass through a metal conduit, the conduit should be ___________.
33. Wires should be held by ___________ to prevent chafing and vibration.
34. Spark plug wires can ___________ if wires are too close together when they serve cylinders that fire consecutively.
35. As long as the insulation is alright, a wire can be considered OK. True or False?
36. A frayed wire can cause a ___________ circuit.
37. A corroded connection will increase ___________ to electrical flow.

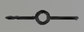
38. The electrical symbols in the left hand column are all numbered. Write down these numbers, one beneath the other. The right hand column lists the items these symbols stand for. Each item has a letter. Match the items to the symbols by placing the letter of the item you have chosen beside the number of the matching symbol.

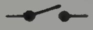
1.  [illegible] ____________

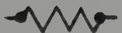
2.  [illegible] ____________

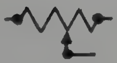
3.  [illegible] ____________

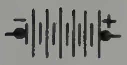
4.  Conection ____________

5.  ____________

6.  Switch ____________

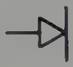
7.  Resistor ____________

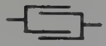
8.  variable resistor ____________

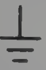
9.  Battery ____________

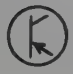
10. + ____________

11. − ____________

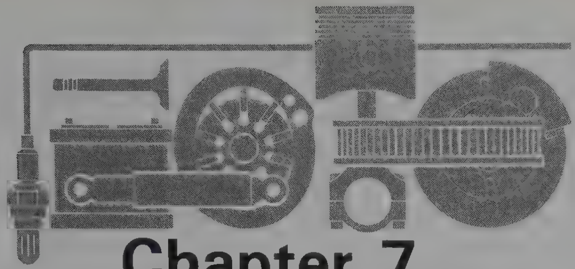
12.  Diodes ____________

13.  Condeson ____________

14.  Ground ____________

15.  transistor ____________

A. Resistor.
B. Circuit Breaker.
C. Wires Crossing - Not Connected.
D. Fuse.
E. Diode.
F. Wires Crossing - Connected.
G. Positive.
H. Terminal.
I. Switch.
J. Rheostat.
K. Transistor.
L. Battery.
M. Negative.
N. Condenser.
O. Ground.



Chapter 7

JACKS, LIFTS, PULLERS, PRESSES, HOLDING FIXTURES

After studying this chapter, you will be able to:

- ☐ List the most commonly used pressing, lifting, pulling, and holding equipment.
- ☐ Select the correct type equipment for the job.
- ☐ Describe safety precautions for jacks, lifts, pullers, presses, and holding fixtures.

A wide assortment of pressing, lifting, and pulling equipment is available in most garages. Proper use of this equipment will both lighten and speed up repair work.

EXTREME CARE MUST BE USED WITH ALL TOOLS CAPABLE OF DEVELOPING HIGH PRESSURES, STRESSES, AND TENSIONS. NEVER USE EQUIPMENT WITHOUT FIRST RECEIVING INSTRUCTIONS FROM SOME PERSON FAMILIAR WITH ITS USE! THERE ARE MANY SAFETY RULES IN THIS CHAPTER. STUDY THEM CAREFULLY!

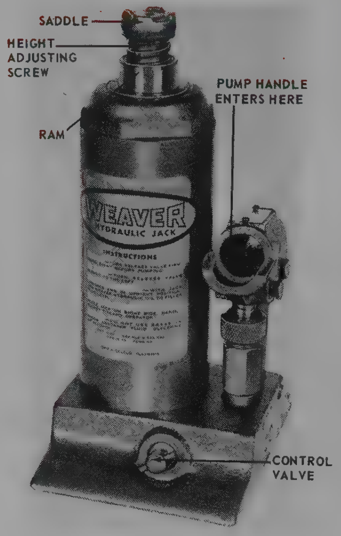


Fig. 7-1. Hydraulic hand jack.

HAND JACK

The hydraulic hand jack is very useful in many applications. It is short, compact, and capable of producing great pressure. It can be used to raise heavy weights, to bend parts, to pull or push parts into alignment. Hydraulic power is quite often used as a power source in small presses.

When using, make sure the jack is securely placed and aligned so that as pressure is developed, it will not slip. Be careful of dropping the jack as it is quite heavy, Fig. 7-1.

HYDRAULIC FLOOR JACK

A floor jack is used to raise a car. It can raise the entire front, back, or side. It is also handy for manuvering cars into tight quarters. The jack is placed under the front or back. The car is then lifted. By pulling on the jack in the direction desired, the car can be moved forward, backward, or sideways.

Floor jacks are available in many sizes with lifting capacities varying from around one to twenty tons (900 to 18 000 kg). Fig. 7-2 illustrates a typical floor jack.

PROPER PLACEMENT IS IMPORTANT

When positioning the jack saddle for lifting, make certain it is securely engaged. Select a spot that will be strong enough to support the load. Never try raising the car by jacking on the engine pan, clutch housing, transmission, tie rods, gas tank, or other weak components.

Proper placement requires care. GET DOWN AND TAKE A GOOD LOOK, WITH AMPLE LIGHT, BEFORE RAISING. If the car is part way up and the jack saddle slips, serious damage can occur. On some cars, jacking one side of one end or near the center of the frame on one side can cause damage. Car

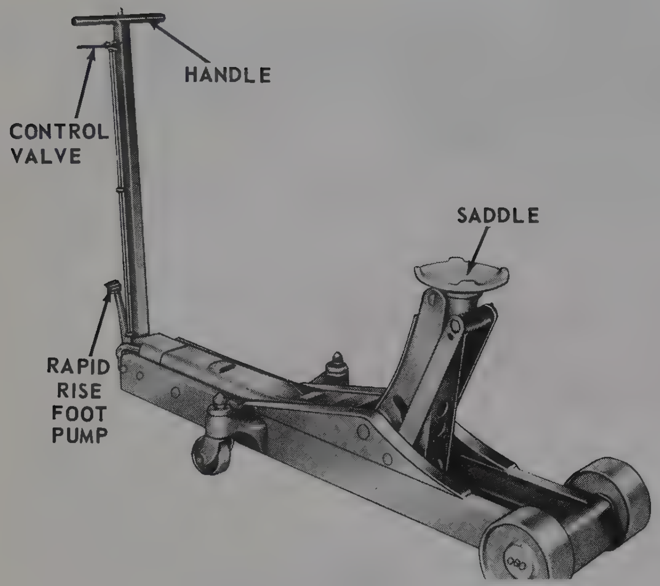


Fig. 7-2. Hydraulic floor jack. By operating the rapid rise foot pump, the saddle is quickly elevated. Heavy pressure can then be developed by working the long handle back and forth. (Weaver)

manufacturers illustrate correct lifting points in their manuals. You must follow the manufacturer's specifications carefully. Fig. 7-3 shows a car being raised by placing the saddle under the center of the differential housing.

NEVER WORK UNDER A VEHICLE SUPPORTED ONLY BY A FLOOR JACK. Once the car is raised to the desired height, place jack stands in the desired location, and lower the weight onto the stands. STANDS MUST BE PROPERLY AND SECURELY PLACED.

The jack may then be removed if desired. If not needed in another area, it may be left in position with a very light lifting pressure to keep it positioned.

JACK STANDS

Jack stands are made in numerous heights and are usually adjustable. The stand in Fig. 7-4 is typical. Note

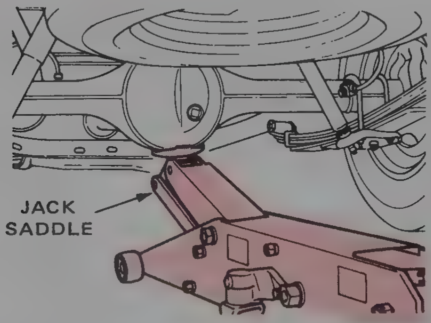


Fig. 7-3. Raising car with floor jack. Make certain saddle is properly positioned. (Honda)

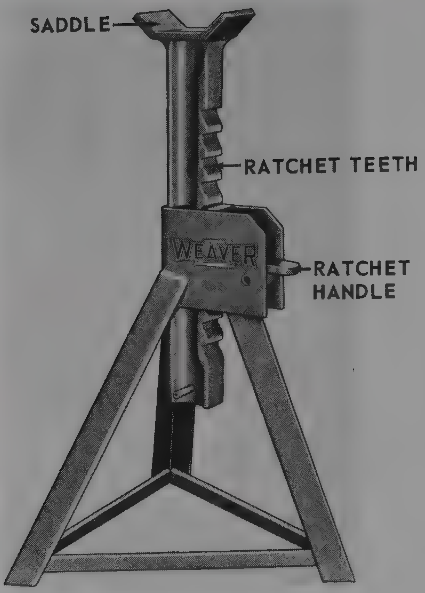


Fig. 7-4. Typical adjustable jack stand.

the ratchet adjustment.

When inserting jack stands, place them in contact with some unit capable of supporting the load. Do not place them in contact with tapered edges that may cause them to slip. Make sure they have a secure "bite." Fig. 7-5 shows a pair of jack stands (often called safety stands) in place under the rear axle housing. Note that the stand tops (saddles) are properly positioned.

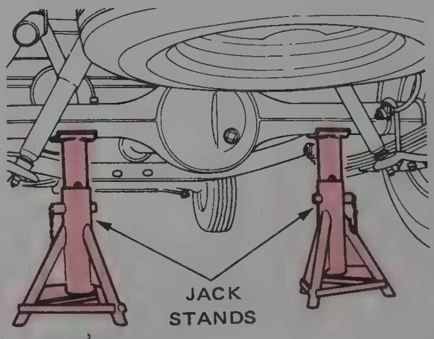


Fig. 7-5. Properly placed jack stands provide safe support. (Honda)

END LIFTS

The end lift can be air (pneumatic) or hydraulically operated. Two basic designs are used. One will reach under the car far enough to contact the rear axle housing. The other design engages the bumper only.

An air-operated long-reach end lift is pictured in Fig. 7-6. This end lift is capable of raising the vehicle much higher than the floor jack.

The bumper lift shown in Fig. 7-7 is also air-

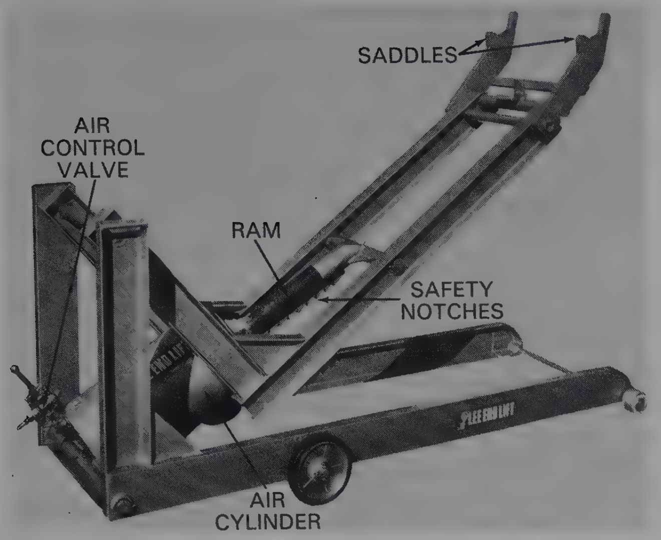


Fig. 7-6. One type of long-reach, air-operated end lift. Notice safety notches on ram. (Hein-Werner, Lee)

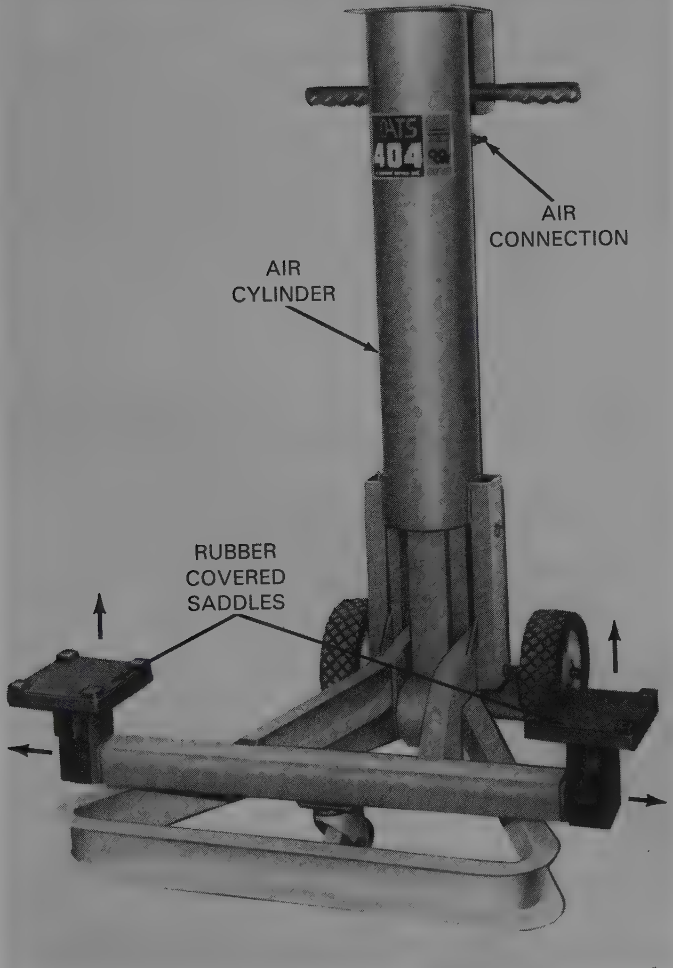


Fig. 7-7. A typical air-operated bumper end lift. Do not use on cars with energy absorbing bumpers. (Coats)

operated. Note the twin rubber covered saddles. The distance between saddles may be varied to engage the bumper where desired. Remember that bumpers, especially near the outer ends, may not be very strong. If the bumper can be used, place the saddles at the main bumper to frame attachment points.

End lifts are generally provided with strong safety locks so the mechanic may safely work beneath the car without jack stands. MAKE SURE THE SAFETY LOCK IS FULLY ENGAGED, AND THAT THE LIFT CONTACT POINTS ARE SOLID. If there is the slightest doubt, use jack stands for additional protection.

FAST, LOW LEVEL AIR LIFT

A handy, quick-acting air lift is illustrated in Fig. 7-8. The car is driven over the lift until the rear wheel is centered in the frame. A control box actuates the rubber air bellow which causes the saddle to lift the car. This jack is useful for washing rear wheels (partially covered by body) and for changing rear wheels.

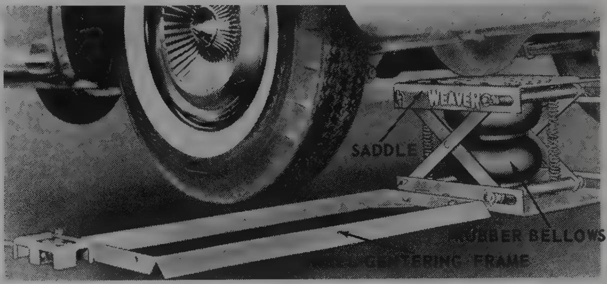


Fig. 7-8. Low level, wash rack lift. Note rubber bellows.

SINGLE POST FRAME LIFT

A single post frame lift leaves both the front and rear of the car completely exposed. It does, however, create some obstruction in the central portion. Fig. 7-9 shows a car in the raised position on a single post frame lift. Note the lift contact points on the frame. REMEMBER: PROPER CONTACT POINTS FOR DIFFERENT CARS VARY. FOLLOW THE MANUFACTURER'S INSTRUCTIONS.

DOUBLE POST FRAME LIFT

The double post frame lift eliminates the single, central post. This leaves the center portion of the car more accessible. As with the single post lift, the car must be carefully centered. In Fig. 7-10, the mechanic has centered the car and is adjusting the swivel lift arms.

An auto is shown in the raised position in Fig. 7-11. The equalizer racks insure that both columns will raise and lower together.

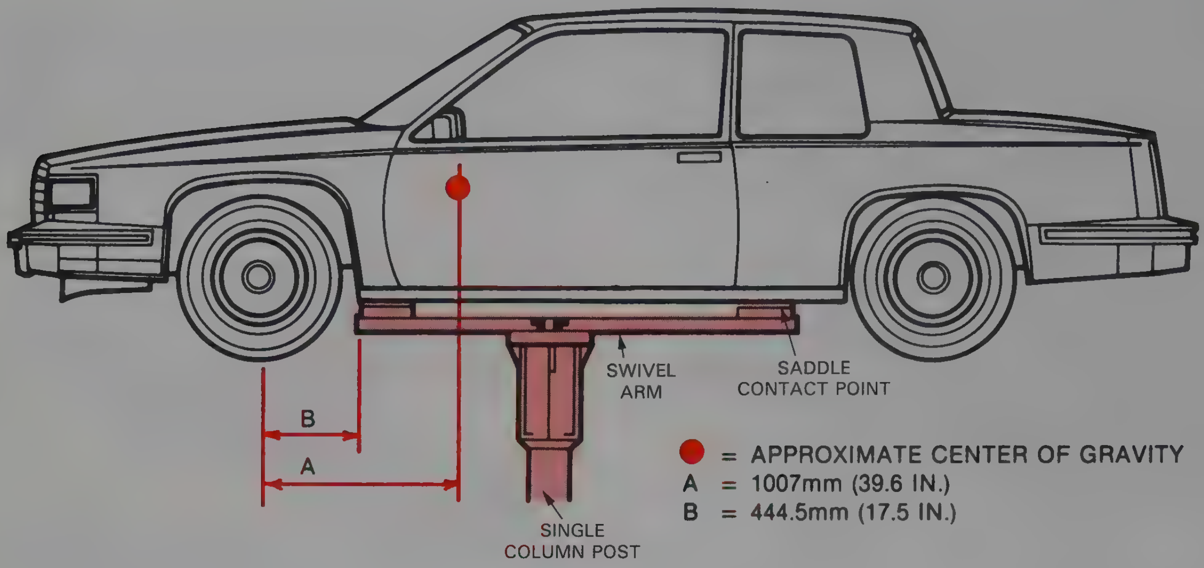

SWIVEL ARM
SADDLE CONTACT POINT
B
A
SINGLE COLUMN POST
● = APPROXIMATE CENTER OF GRAVITY
A = 1007mm (39.6 IN.)
B = 444.5mm (17.5 IN.)

Fig. 7-9. Single post frame lift. Note vehicle approximate center of gravity and measurements. This provides for proper placement of this car on lift. (Cadillac)

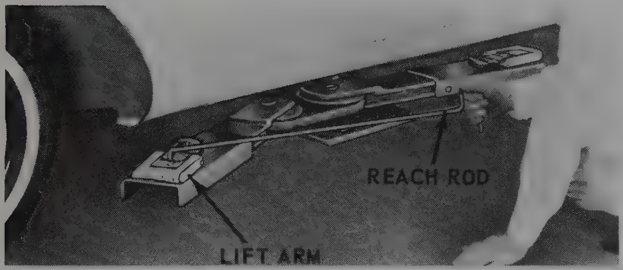

REACH ROD
LIFT ARM

Fig. 7-10. Adjusting swivel arms on double post frame lift.

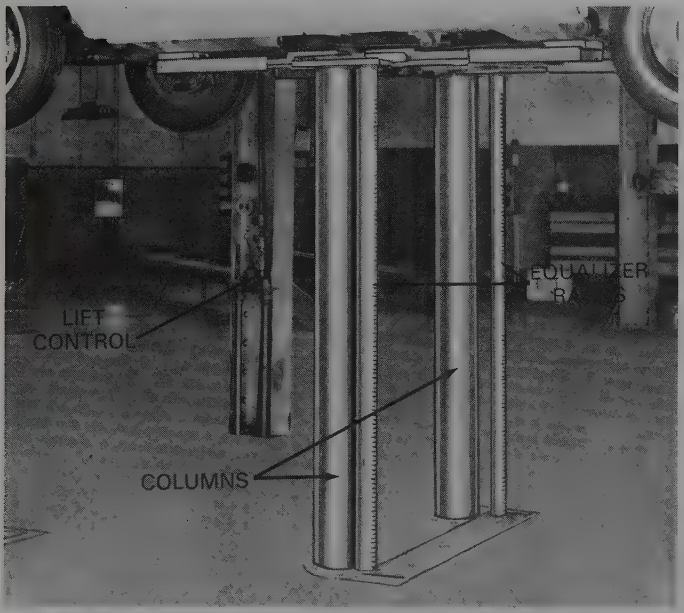

LIFT CONTROL
EQUALIZER RAILS
COLUMNS

Fig. 7-11. Double post frame lift. Car must be carefully centered.

DOUBLE POST SUSPENSION LIFT

The double post lift, pictured in Fig. 7-12, contacts the front suspension arms, and either the rear axle housing, or rear wheels. The front lift column can be moved forward or backward to adjust for various wheelbase lengths. This type of lift presents a minimal amount of under-car obstruction. On some models, a single column can be raised, thus acting as an end lift when so desired.

DRIVE-ON LIFT

The drive-on lift, Fig. 7-13, offers placement speed but does present a relatively large obstruction area.

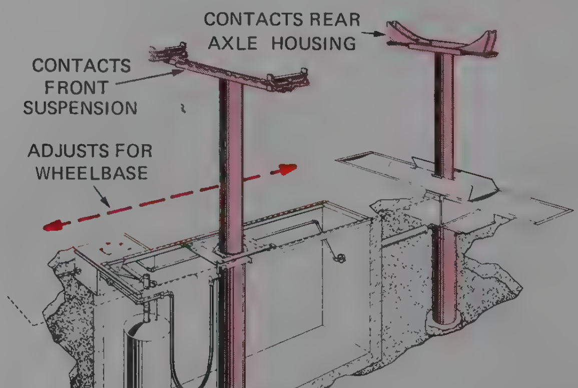

CONTACTS REAR AXLE HOUSING
CONTACTS FRONT SUSPENSION
ADJUSTS FOR WHEELBASE

Fig. 7-12. Double post suspension lift. This lift creates very little under-car obstruction. (Dresser Industries)

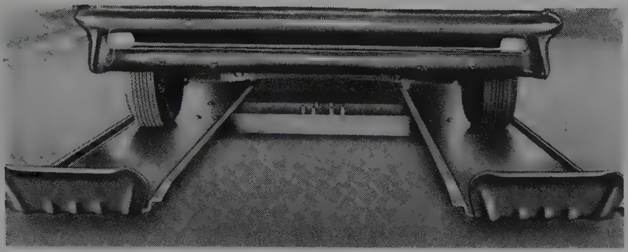


Fig. 7-13. Drive-on lift. (Weaver)

CHOICE OF LIFTS

As you have noticed, each lift offers some advantages and disadvantages, depending on the work to be performed. Many shops provide several types so that the mechanic will have some choice in selecting a lift appropriate to the repair job.

SAFETY CONSIDERATIONS

Floor jacks, end lifts, and frame lifts must all be used with extreme care. Remember that many cars can weigh TWO TONS (1 800 kg) or over. Each year a number of mechanics are killed or injured by careless use of lift equipment. In addition to using safe operating procedures, it is imperative that lift equipment be kept in sound operating condition. Cracked or bent parts, faulty safety locks, leaking cylinders, and other problems must not be tolerated.

The following list of safety precautions apply to all types of lifting equipment. Study them carefully, OVER AND OVER, until you remember each and every one.

1. Lift saddles must be properly located and in secure contact.
2. When using a floor jack, always use jack stands.
3. Once saddles are located, apply some pressure. Then, stop and examine them again before lifting the car.
4. If an end lift or a floor jack is being used on a rough or soft surface, release the hand brake and place the transmission in neutral. Since either the car or lift must move when lifting or lowering, this will prevent saddle slippage.
5. When raising the entire car, watch for any side or overhead obstructions.
6. Make certain that the lift safety lock is securely engaged before getting under the car.
7. Never remove a lift or jack from another mechanic's setup without asking the mechanic first.
8. If it is necessary to change the raised height of the vehicle during the job, do not move it until all persons are "out from under."
9. Always check for equipment, parts, or personnel beneath the car before lowering.
10. Lower SLOWLY and watch the car during the entire descent.

TRANSMISSION JACKS

A transmission jack is essential to the safe, efficient removal and installation of automatic transmissions transfer cases and other large assemblies. The saddle utilizes a series of adapters and a binder chain or strap for secure attachment. The saddle can be raised and

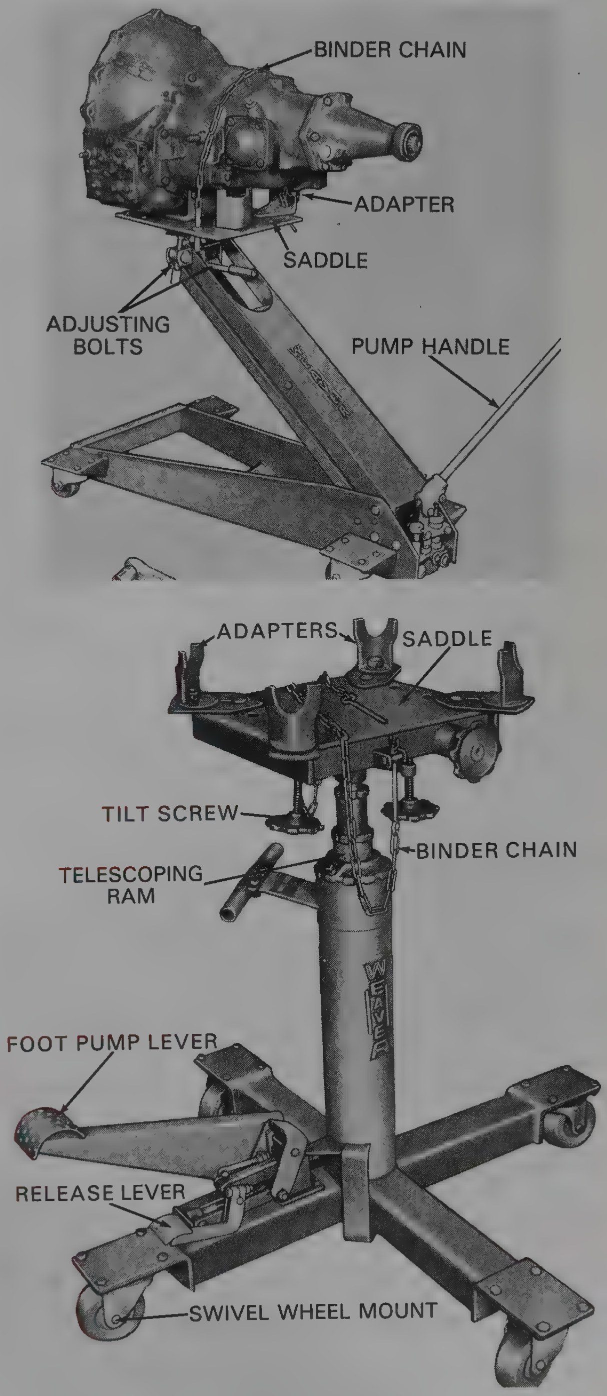


Fig. 7-14. Two types of transmission jacks. Top—Typical transmission jack constructed like a floor jack. Bottom—High reach transmission jack. These jacks may also be used to handle engines that are removed from under car. (Weaver)

lowered hydraulically and tipped in any direction through the use of adjusting screws. Fig. 7-14, Top, shows a typical jack with the transmission in place. Fig. 7-14, Bottom, illustrates a high reach transmission jack.

When using a transmission jack, be certain to attach the transmission securely. It is heavy and if it slips, it could cause serious injury.

WHEEL DOLLY

Shops doing truck repair find a wheel dolly helpful in removing and installing large wheel assemblies. Note the use of a hydraulic hand jack on the dolly in Fig. 7-15.

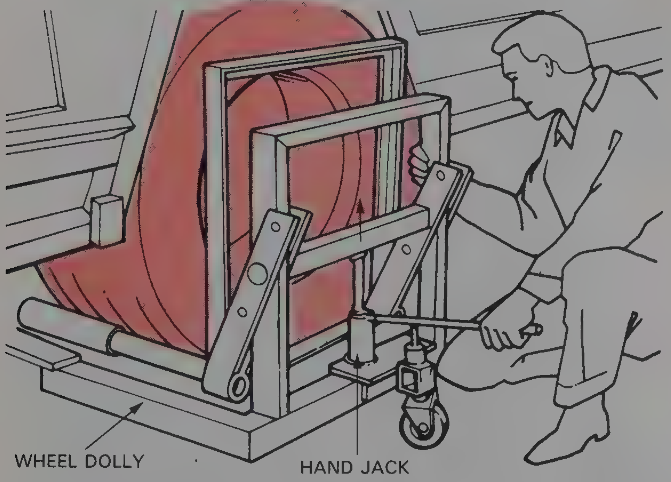


Fig. 7-15. One type of hydraulically actuated wheel dolly. These aid greatly when removing and installing heavy wheel-tire assemblies. (Ford)

PORTABLE CRANE AND CHAIN HOIST

The portable crane and the chain hoist are excellent tools for engine removal. They can also be used to lift heavy parts to bench tops and truck beds. Fig. 7-16 depicts a heavy-duty portable crane being used to pull an engine. Fig. 7-29 shows another type.

IMPORTANT SAFETY RULES TO OBSERVE WHEN USING A CRANE OR CHAIN HOIST ARE:

1. Stand clear at all times.
2. Lower the engine as soon as it is clear of the car.
3. Never roll the crane with the load high in the air. Keep it just above the floor.
4. Never leave the engine suspended while working on it. Lower to the floor or place on a suitable engine stand.
5. Never leave the crane or hoist with the load suspended. If you must leave, even temporarily, lower it.
6. When moving heavy loads, alert your fellow mechanics.
7. Never give the load, when suspended by a chain hoist attached to an overhead track, a hard shove and let it coast along. Move it slowly and stay with it.
8. Attaching cables, chains, bolts, and other lifting devices must have ample strength.
9. When using nuts to attach lift cables, the nut must be fully on. When using cap screws, they must have a thread engagement depth one and one-half times the diameter.

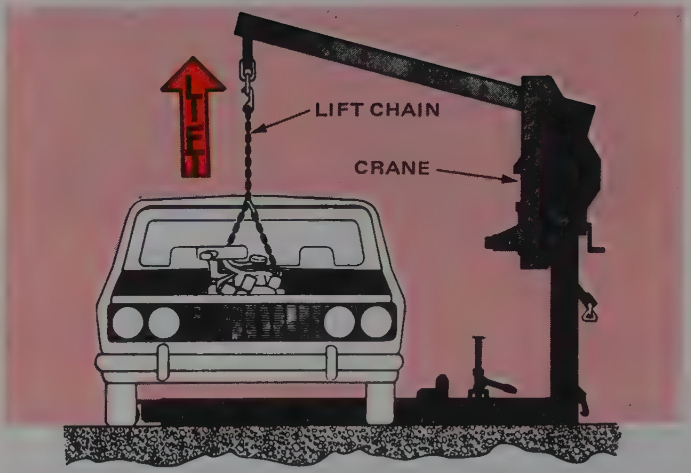


Fig. 7-16. Portable crane being used to pull an engine. (Guy-Chart Systems)

More information on the use of this equipment for engine work will be given in the section on engine removal and installation.

EXTENSION JACK

An extension jack is a valuable tool for exerting mild pressure and for holding parts to leave both hands free. Some are adjusted up and down with a screw. Others are hydraulically operated. A hydraulic extension jack is pictured in Fig. 7-17.

HYDRAULIC PRESS

Removing bearings, straightening shafts, and pressing bushings are just a few of the many jobs that can be performed on a hydraulic press. The press is far superior to striking tools because the pressure is smooth and controlled. There is no metal “upsetting” shock, and enormous pressures can be generated. Fig. 7-18 illustrates a typical floor hydraulic press set up to remove an axle bearing. A wheel hub and drum assembly is also in place for wheel lug work.

When using a hydraulic press, make sure the table pins are in place and that the table winch is slacked off. Failure to do this can break the winch gear or cable.

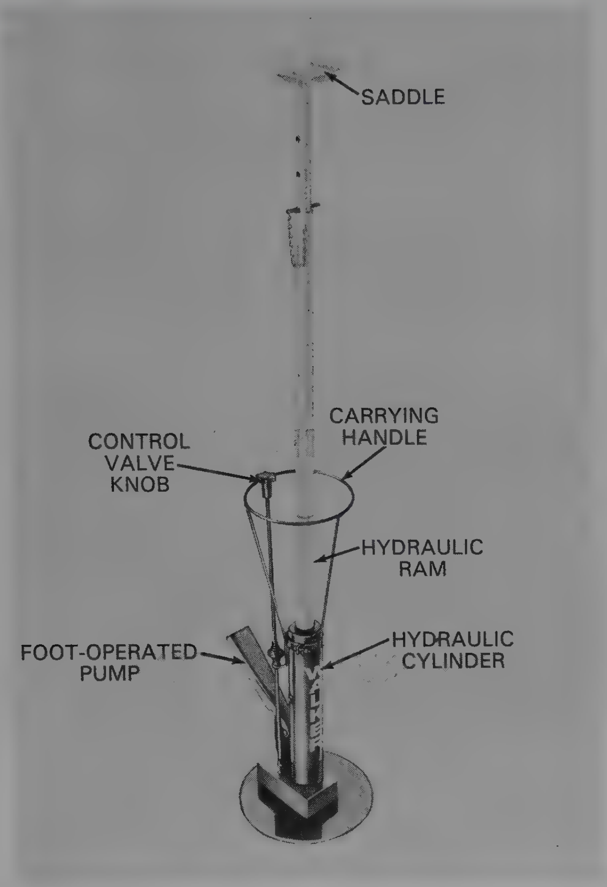

SADDLE
CARRYING HANDLE
CONTROL VALVE KNOB
HYDRAULIC RAM
FOOT-OPERATED PUMP
HYDRAULIC CYLINDER

Fig. 7-17. One type of extension jack. This jack is raised hydraulically by foot-operated pump. It has a capacity of 1 ton (900 kg). (Lincoln St. Louis)

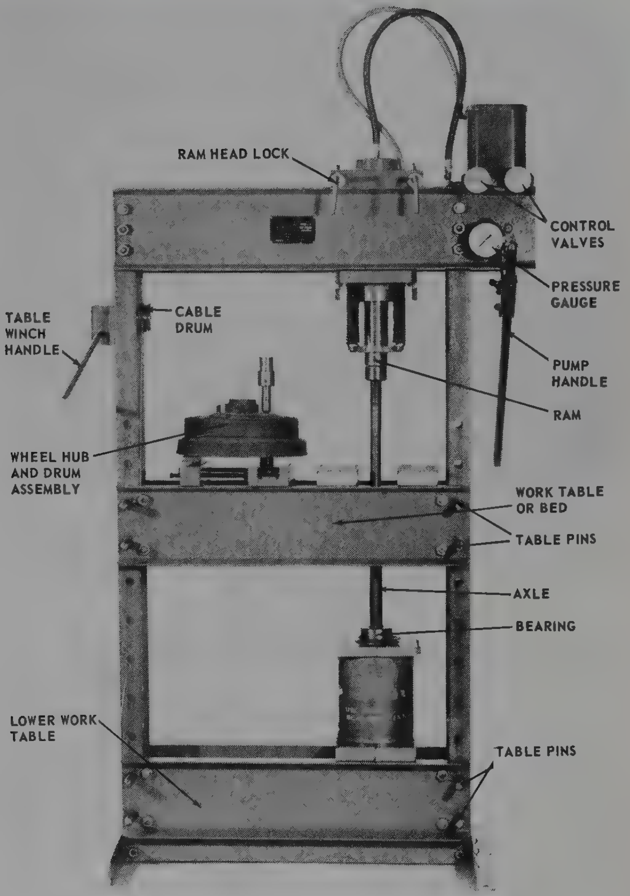

RAM HEAD LOCK
CONTROL VALVES
PRESSURE GAUGE
TABLE WINCH HANDLE
CABLE DRUM
PUMP HANDLE
RAM
WHEEL HUB AND DRUM ASSEMBLY
WORK TABLE OR BED
TABLE PINS
AXLE
BEARING
LOWER WORK TABLE
TABLE PINS

Fig. 7-18. Typical floor model hydraulic press. (F.A. Nugier Co.)

PORTABLE HYDRAULIC POWER UNIT

There are many occasions when heavy, controlled pressures are needed for part alignment, and body and fender work. The portable hydraulic power set, shown in Fig. 7-19, provides a number of useful adapters that allow the tool to be used for many jobs.

In Fig. 7-20, a hydraulic set is being used to move vehicle frame members back into position following a collision.

SAFETY PRECAUTIONS

All hydraulic pressing and pulling tools are potentially dangerous if improperly used. General safety rules applicable to all types are:

1. Stand free while pressure is applied.
2. Only apply enough pressure to do the job.
3. Shield brittle parts such as bearings to protect against flying parts.
4. Engage ram securely and in line with work.
5. When any chance of part breakage is present, wear goggles.

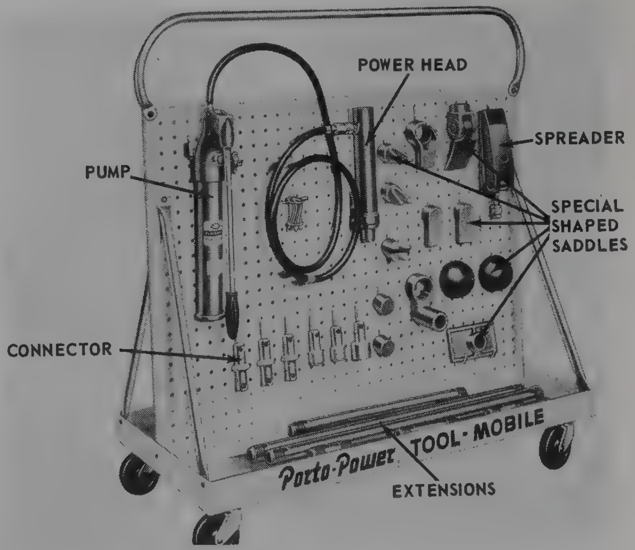

POWER HEAD
SPREADER
PUMP
SPECIAL SHAPED SADDLES
CONNECTOR
Porto-Power TOOL-MOBILE
EXTENSIONS

Fig. 7-19. Portable hydraulic power unit and accessories. (Blackhawk)

6. If work must be performed while maintaining pressure, be careful to keep out of line with the tool.
7. Be careful of part snap-back if the tool slips.

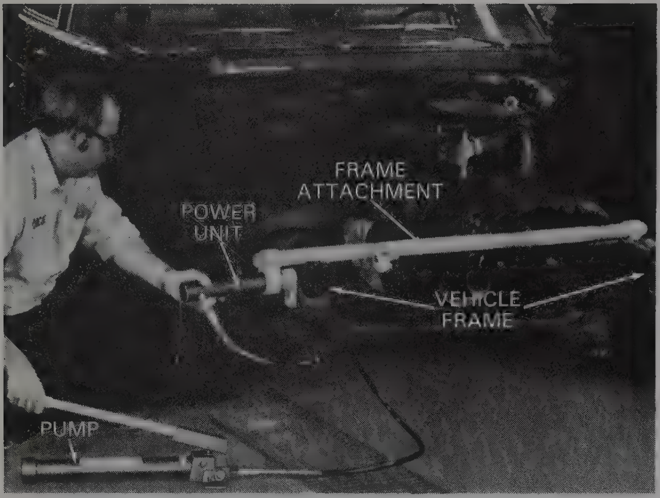

FRAME ATTACHMENT
POWER UNIT
VEHICLE FRAME
PUMP

Fig. 7-20. Portable hydraulic power unit being used with attachments to straighten a damaged frame. (Lincoln St. Louis)

HYDRAULIC AND MECHANICAL PULLERS

A good assortment of pulling tools is important. An attempt to "get by" with a few pullers will result in a great deal of wasted time and damaged parts. Many jobs are almost impossible without proper pullers.

Pullers can be mechanically or hydraulically operated. Both have certain advantages.

THREE TYPES OF PULLING JOBS

All pulling jobs will be covered in the three basic setups:

1. Pulling an object (gear, pulley, bearing, retainer, etc.) from a shaft.
2. Pulling a shaft (axle, transmission, pinion, etc.) from an object.
3. Pulling an object (bearing outer ring, cylinder sleeve, camshaft bearings, etc.) from a housing bore. Figs. 7-21, 7-22, and 7-23 illustrate the three basic pulling jobs.

A typical hydraulic puller is shown in Fig. 7-24.

Several universal-type mechanical pullers are pictured in Fig. 7-25.

Store pullers on a board and keep related parts and adapters together. Some shops mount individual puller sets on "tote" boards so all parts may be carried to the job.

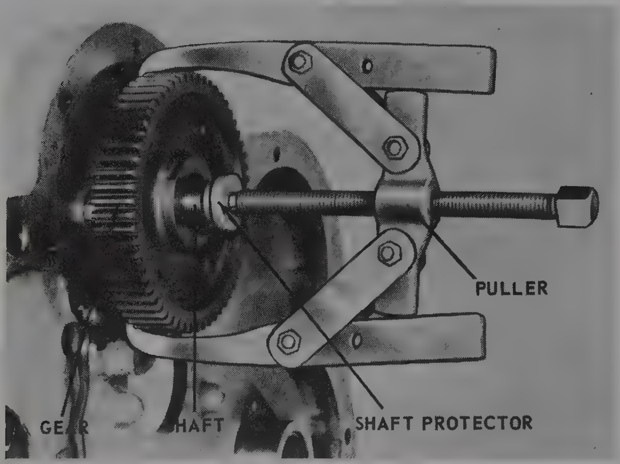

PULLER
GE R
HAFT
SHAFT PROTECTOR

Fig. 7-21. Basic pulling job - pulling an object (gear) from a shaft. (O.T.C.)

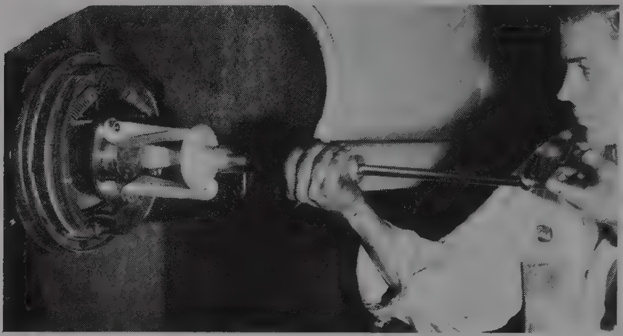


Fig. 7-22. Basic pulling job - pulling a shaft (axle) from an object.

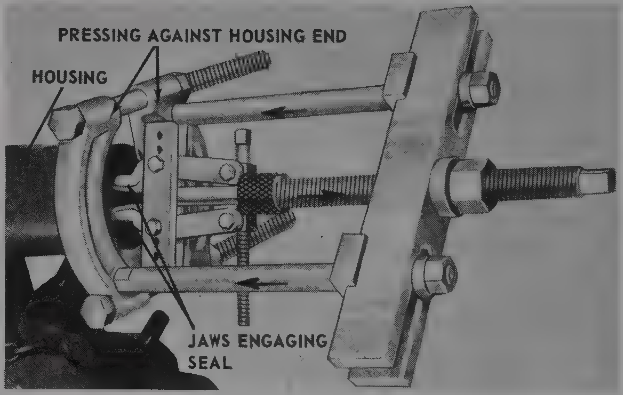

PRESSING AGAINST HOUSING END
HOUSING
JAWS ENGAGING SEAL

Fig. 7-23. Basic pulling job - pulling an object (seal) from a housing bore.

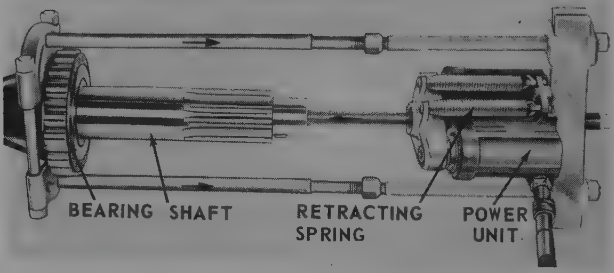

BEARING
SHAFT
RETRACTING SPRING
POWER UNIT

Fig. 7-24. Hydraulic puller removing roller bearing from pinion shaft.

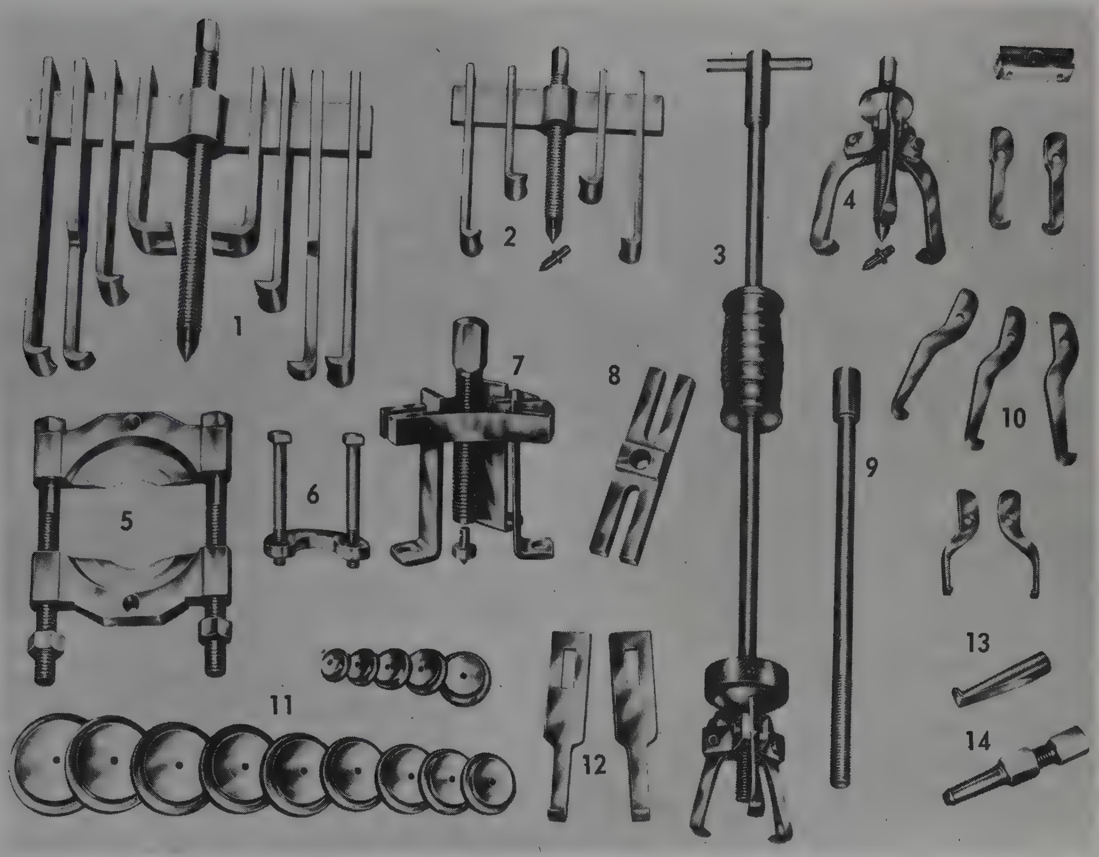


Fig. 7-25. Mechanical pullers. 1—Heavy duty. 2—Medium duty. 3—Slide hammer. 4—Three-jaw. 5—Split yoke for grasping behind gears, bearings, or other parts. 6—Rear wheel hub adapter. 7—Rear wheel hub puller. 8—Slotted cross arm. 9—Short slide hammer rod. 10—Reversible puller jaws. 11—Step plates for pulling and installing bushings, bearings, and seals. 12—Timing gear jaws. 13—Single-jaw. 14—Clutch pilot bearing puller. (Proto)

REPAIR STANDS

Engine block, head, transmission, and differential repairs are greatly facilitated by using a repair stand. Many types are available. When using repair stands, attach the unit securely to the stand. Carelessness here can be costly.

Fig. 7-26 shows an engine block mounted in a stand. Note the crank that allows the engine to be turned to various positions.

A transmission mounted in a similar stand is pictured in Fig. 7-27.

Two cylinder heads are attached to a bench fixture in Fig. 7-28. As with all stands, tighten holding screws securely.

HAND LIFTING

Occasionally, a mechanic will want to hand lift an object. There are several important points to remember in order to avoid injury.

1. Never overlift: If the object is quite heavy, ask for help or use a lift, Fig. 7-29.

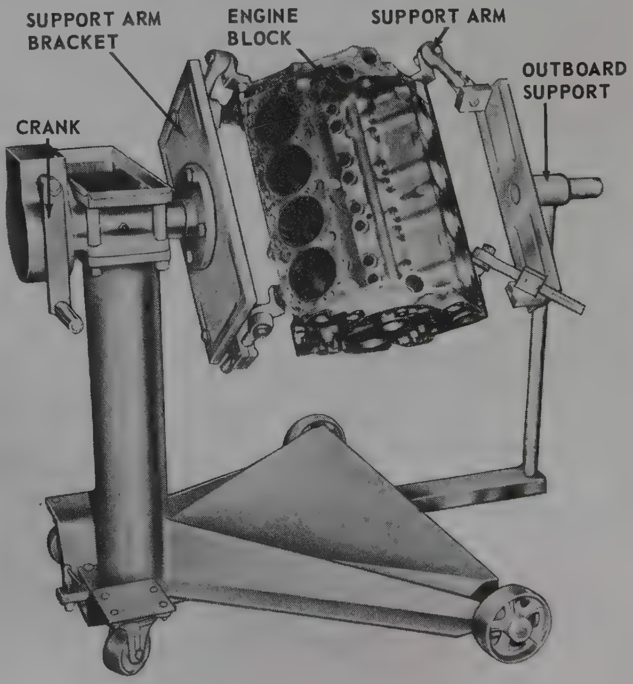


Fig. 7-26. One type of engine repair stand.

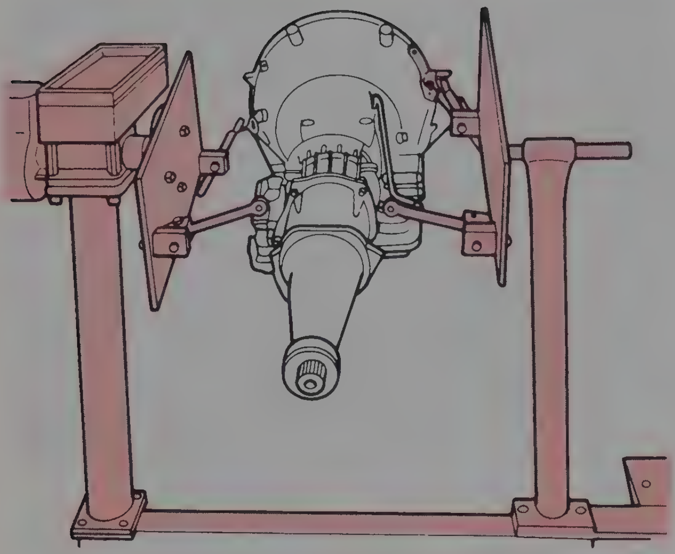


Fig. 7-27. Transmission in repair stand. (Ford)

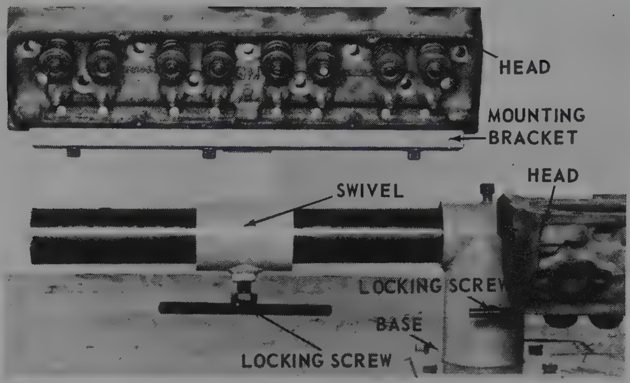


Fig. 7-28. The cylinder head holding fixture simplifies repair work. (Storm-Vulcan)

2. Keep your back straight and lift with your legs. Keep legs as close together as possible.
3. Unless you KNOW you can handle the weight, never hold some part with one hand while you remove the last fastener with the other.
4. Get a firm grip to prevent dropping the unit - possibly on your feet.
5. Do not "show off your strength" by attempting to lift heavy objects. Remember: If all a garage needed was STRENGTH, you could be replaced with a JACK.
6. Be careful of sharp edges.

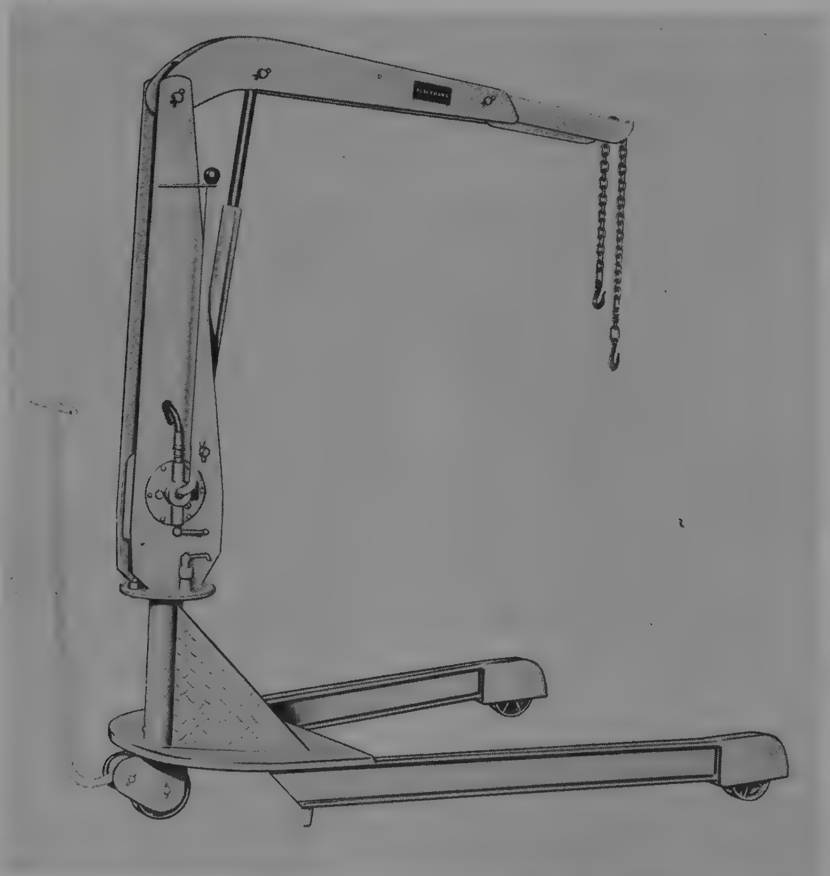


Fig. 7-29. A portable crane such as this, is a very handy tool. (Blackhawk)

SUMMARY

Mechanics should be familiar with various lifting, pulling, and pressing tools to make their work easier and more efficient.

The tools covered in this chapter must be used with extreme caution. Observe all recommended safety precautions.

Hand jacks have many applications.

Floor jacks are very handy for raising and positioning cars. Never get under a car supported by a floor jack. Use jack stands to support the car. Be careful not to damage parts when lifting.

End lifts have a fairly high reach and support the car safely. Make sure the safety lock is in position.

Single and double post lifts can be designed to engage either the frame, suspension system, or the tires. All have advantages and disadvantages.

Cars must be centered on the lift and the lifting brackets should be properly and securely placed.

Use care when determining lift points to avoid chassis distortion or part damage.

Transmission jacks, wheel dollies, and portable cranes facilitate the removal and installation of heavy parts.

Hydraulic presses are superior to striking tools. Use them whenever possible and use with care.

The shop should have a wide selection of pulling equipment.

Repair stands for engines, transmissions, and other assemblies make the job faster, safer, and easier. Always place unit in stand securely.

SUGGESTED ACTIVITIES

1. Make it a point to receive instruction in the use of all lifting, pressing, and pulling equipment. Practice using them.
2. Maintain a file of up-to-date catalogs covering all types of shop equipment. Study them. Even though your shop may not have all the different types, you should be fully informed as to what is available.

LUCK? - DON'T YOU BELIEVE IT!

The auto shop, by its very nature, presents numerous hazards. Despite this, many mechanics work at the trade for a lifetime without serious injury. Others, however, are frequently injured. Some are killed. Is shop safety then, a matter of luck?

Absolutely not! The major things that will keep you safe on the job are:

1. An understanding of and respect for the dangers involved.
2. Consistently following all safety rules.
3. The development of a "think before you act" attitude.

On each and every task, apply these suggestions. Apply them over and over until they become habits—habits which may someday save you from serious injury or death.

KNOW THESE TERMS

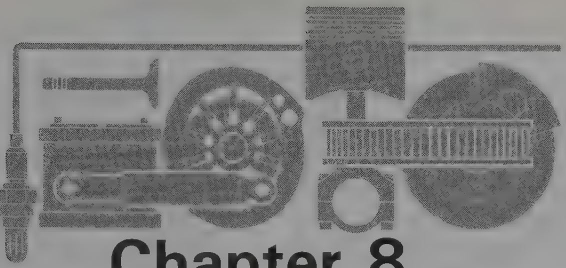
Hydraulic hand jack, Hydraulic floor jack, Jack stand, End lift, Lift saddle, Transmission jack, Wheel dolly, Portable crane, Chain hoist, Extension jack, Hydraulic press, Hydraulic puller, Engine stand, High reach jack, Ram, Control valve, Foot pump, Pneumatic, Air operated, Slide hammer.

QUIZ - Chapter 7

1. A car supported on a good, well placed floor jack is safe to work under. True or False?
2. Jack contact points are not important as long as the jack gets a good grip. True or False?
3. End lifts, if properly designed, provide holding power sufficient to allow the mechanic to work beneath the car without jack stands. True or False?
4. What type would better lend itself to drive line work - the single-post frame or the double-post frame lift?
5. The drive-on lift is ideal for pulling wheels. True or False?
6. Never ______________ a lift without checking beneath the car.
7. Lift height can safely be varied without getting out from under the car. True or False?
8. Despite the type of lift, always check the _______ lock before getting under the car.
9. A lift should be raised and lowered__________.
10. Transmissions are best handled with a __________ ____________.
11. Heavy wheel assemblies are easily handled with a ___________ ___________.
12. When moving an object with a portable crane, keep the load as ___________ as possible.
13. An engine, suspended from a crane, is safe to work on. True or False?
14. When attaching lift chains and cables with cap screws, how much thread engagement is necessary?
15. Stand _______________ of heavy loads.
16. Of what use is an extension jack?
17. Give three reasons why a hydraulic press is superior to striking tools.
18. What tool is very helpful in straightening heavy body sections?
19. List the three basic pulling setups.
20. When working on engines, transmissions, and other assemblies, they are best placed on an appropriate ___________ ___________.
21. Give three safety precautions concerning hand lifting.

22. List seven safety rules regarding jacks and lifts.
23. List five safety rules regarding portable cranes and chain hoists.
24. Give five safety rules to observe when using hydraulic pressing or pulling tools.

A typical adjustable, 1000 lb. (450 kg) capacity engine stand. Note removable drip pan. (Owatonna Tools)



Chapter 8

SOLDERING, BRAZING, WELDING, CRACK DETECTION AND REPAIR

After studying this chapter, you will be able to:

☐ Explain how to solder.

☐ Describe the procedures for brazing and welding metal.

☐ Summarize crack detection methods.

☐ Explain how to repair cracks in parts.

This chapter is designed to provide basic techniques, machine operations, and safety rules pertaining to soldering, welding, and brazing.

Most welding and brazing is confined to the body shop. However, you will find that welding skills can be used on many different jobs. Students of auto mechanics should take at least one basic course in the welding field.

USE CARE WHEN WELDING, HEATING, OR CUTTING - FIRE OR EXPLOSION CAN OCCUR. KEEP AWAY FROM FUEL TANKS, BATTERIES, AND OTHER FLAMMABLE ITEMS.

SOLDERING

Soldering can be defined as the act of joining two pieces of metal through the use of a lead and tin alloy. There is no actual fusion (melting together) involved. The solder, when the base metal is heated to the correct temperature, dissolves a minute "skin" on the metal. Upon cooling, the solder and "skin" amalgamate (mix together) thus forming a tight bond. See Fig. 8-1.

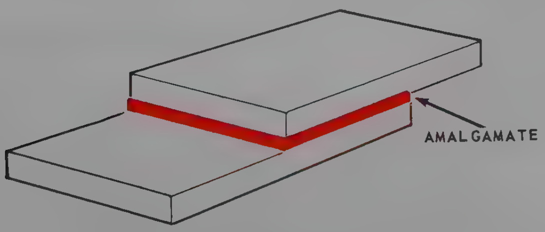


Fig. 8-1. The solder and metal "skin" amalgamate upon cooling thus forming a tight bond.

In soldering, the pieces to be joined should fit together as closely as possible. The less solder separating the parts, the stronger the joint.

SOLDER

Solder is a mixture of lead and tin plus minute traces of zinc, copper, aluminum, and other substances.

The proportion of tin to lead affects both the melting point (point at which solder becomes a full liquid) and the plastic range (temperature span from lowest point at which solder becomes mushy or plastic, to highest point just before plastic mixture liquifies).

You will note from Fig. 8-2 that pure lead melts at 621°F (328°C). Pure tin melts at 450°F (232°C). A mixture of about 63 percent tin to 37 percent lead will melt at 361°F (183°C). Study the chart in Fig. 8-2. Note how temperature and plastic range is affected by alloying in different proportions. A solder that has a wide plastic range is required for car body work.

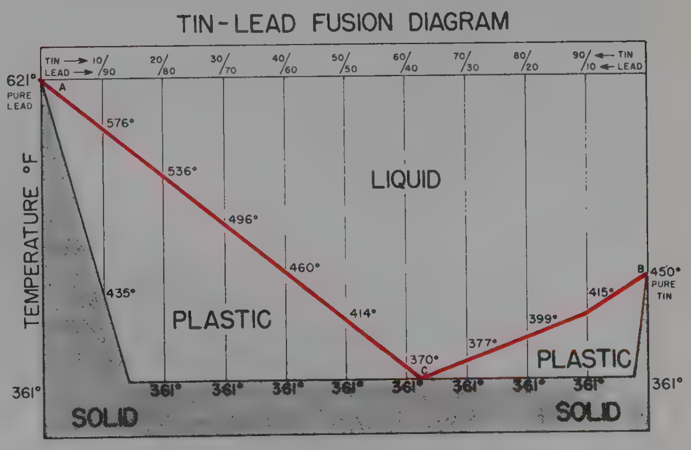


Fig. 8-2. Tin-lead alloy plastic range and melting point chart. (Kester)

Commonly used solders are 40/60 (40 percent tin, 60 percent lead), 50/50, and 60/40. Solder is available in bars or ingots for plumbing, and body and fender work. Flux core wire solder (wire solder with a hollow center filled with flux), solid wire solder, and solder ground into fine grains and mixed with flux, are used for general soldering.

SOLDERING FLUX

Soldering obviously heats the metal. In so doing, it accelerates oxidization (surface of metal combining with oxygen in air). This leaves a thin film of oxide on the surface that tends to reject solder. It is the job of the flux to remove this oxide and prevent the reoccurrance during the soldering process.

Chloride or acid flux is excellent for use on radiators and other soldering where a corrosive and electrical conductive residue (flux remaining on work after soldering) is not harmful. Hot water should be used for cleanup after soldering. BE SURE TO KEEP ACID FLUX OUT OF YOUR EYES.

Organic flux is somewhat like the acid type, but is less corrosive. The flux residue becomes flaky and soft. It can be readily removed by dusting, tumbling, or wiping with a damp cloth. Its effectiveness is lost if subjected to sustained high temperatures.

Rosin or resin type flux MUST BE USED FOR ALL ELECTRICAL WORK. The residue will not cause corrosion, nor will it conduct electricity. The residue may be removed with kerosene or turpentine.

A special flux is required for soldering aluminum.

SOLDERING IRONS

The soldering iron, sometimes called a copper, should be of ample size for the job. An iron that is too small will require excessive time to heat the work and may never heat it properly. The proper size iron will bring the metal up to the correct soldering heat (around 525-575°F or 274-302°C) quickly and will produce a good job.

Plain irons or coppers must be placed in a gas flame or in an electric furnace for heating. They range in size from around 1/2 lb. (224 g) for light work, up to several pounds for heavier tasks.

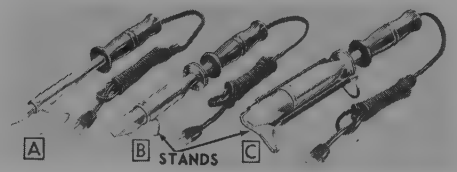


Fig. 8-3. Handy size soldering irons. A—Light duty. B—Medium duty. C—Heavy duty. (Snap-On Tools)

Electric irons are fast and efficient. A 100-watt size is recommended for light work, a 200-watt size for medium work, and a 350-watt iron for heavier work. Wattage will vary - these are approximate size recommendations. See Fig. 8-3.

For electrical wiring, a soldering gun as shown in Fig. 8-4 is ideal. The tip reaches soldering heat in a matter of seconds.

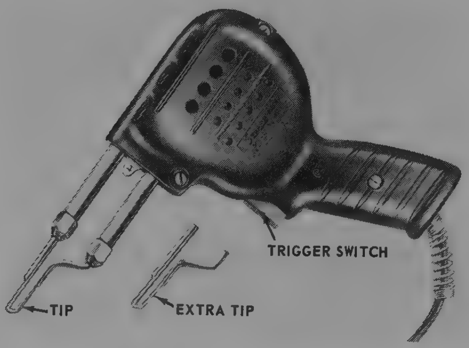


Fig. 8-4. A soldering gun such as this works fast. (Snap-On Tools)

CLEANING WORK

All traces of paint, rust, grease, and scale must be removed. The grinding wheel, wire brush, file, steel wool, emery cloth, and cleaning solvent are all useful in preparing the surface for soldering. Remember that GOOD SOLDERING REQUIRES CLEAN, WELL-FITTED SURFACES.

TINNING THE IRON

The soldering iron tip is made of copper. Through the solvent action of solder and prolonged heating, it will pit and corrode. An oxidized or corroded tip will not satisfactorily transfer heat from the iron to the work. It should be cleaned and tinned. Use a file and dress the tip down to the bare copper. File the surfaces smooth and flat. See Fig. 8-5.

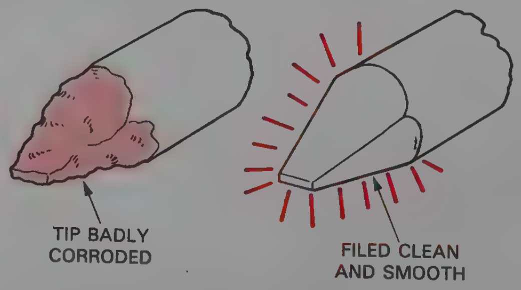


Fig. 8-5. File tip surfaces flat and smooth.

Then, plug the iron in. When the tip color begins to change to brown and light purple, dip the tip in and out of a can of soldering flux (rosin core). Quickly apply rosin core wire solder to all surfaces. If no paste flux is available, rosin core wire solder will do. However, dipping the tip provides a faster and usually better tinning job.

The iron must be at operating temperature to tin properly. When the iron is at the proper temperature, solder will melt quickly and flow freely. NEVER TRY TO SOLDER UNTIL THE IRON IS PROPERLY TINNED. See Fig. 8-6. If during tinning, a surplus of solder adheres to the tip, wipe off the excess with a rough textured cotton rag.

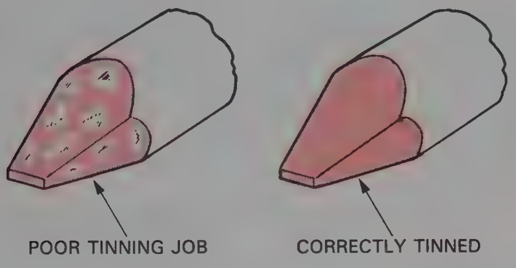


Fig. 8-6. Tip must be properly tinned.

Some shops use a block of sal ammoniac to aid in tinning. The hot iron is rubbed on the block as solder is applied.

HOLDING THE IRON

The iron must be held so that the flat surface of the tip is in full contact with the work. This will permit a maximum transfer of heat. Look at Fig. 8-7.

APPLY SOLDER TO EDGE OF IRON

Apply the wire solder at the edge of the iron where it contacts the work. This will release the flux where it will do the most good. Flowing solder at this point will also provide a mechanical bond between the iron and the work. This will speed up heat transfer, Fig. 8-8.

WORK MUST BE HOT

Pieces to be joined by soldering should be heated so the solder is melted by heat in the metals to be soldered together. When this is done, solder will flow readily and a good job will result. If the solder melts slowly and is pasty looking, the work is NOT hot enough. If using a gas flame to heat the parts, be careful to avoid overheating.

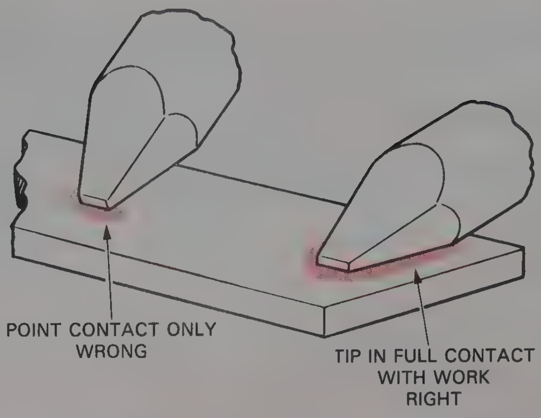


Fig. 8-7. Hold tip flat against work.

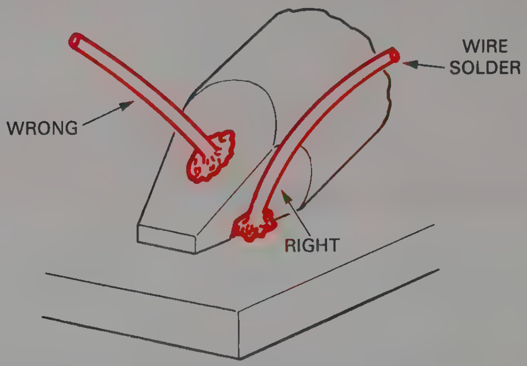


Fig. 8-8. Apply solder to edge of iron where it contacts work.

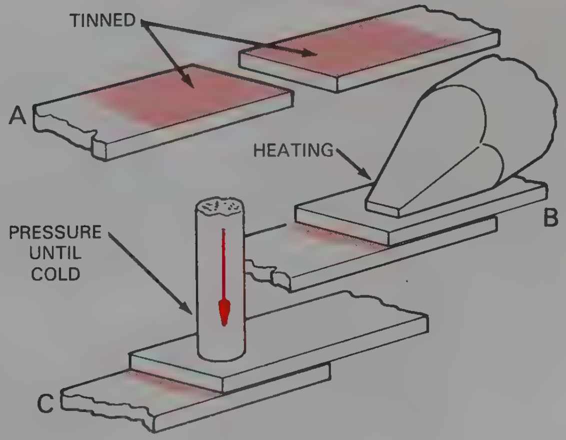


Fig. 8-9. "Sweating" two pieces of metal together. A—Tinning parts. B—Place together and heat. C—Hold tightly together until solder sets.

SWEATING

Two pieces may be joined by tinning the contact surface of each, placing them together, and applying heat. When the tinning metal melts, the pieces are held in firm contact. This process is called sweating. It produces a strong union, if properly done. See Fig. 8-9.

SOLDERING WIRE SPLICES

Apply the tip flat against the splice. Apply rosin core wire solder to the flat of the iron where it contacts the wire. As the wire heats, the solder will flow through the splice, Fig. 8-10.

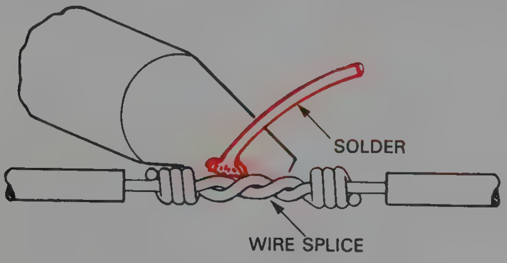


Fig. 8-10. Soldering a wire splice.

DO NOT MOVE WORK UNTIL COOL

When joining two or more pieces by soldering, be careful not to disturb them until the solder has set (cooled to solid state). If they are moved while the solder is still in a pasty state, fracture lines will be set up that will produce a weak joint.

RULES FOR GOOD SOLDERING

1. Clean area to be soldered.
2. Parts should fit closely together.
3. Iron must be of sufficient size and must be hot.
4. Iron tip must be tinned.
5. Apply full surface of tip flat to work.
6. Heat metal to be joined until solder flows readily.
7. Use proper solder and flux for job at hand.
8. Apply enough solder to form a secure bond but do not waste.
9. Do not move parts until solder sets.
10. Place hot iron in a stand or on a protective pad.
11. Unplug electric iron as soon as you are finished.

BRAZING

In brazing, the temperatures involved are higher than in soldering (above 800°F or 427°C).

Brazing consists of heating the work to a point high enough to melt the brazing material but not the work itself. Steel, for example, is brought to a dull red heat. A suitable brazing rod is brought into contact with the heated joint and melted. Capillary action (attraction between a solid and a liquid) draws the brazing alloy into the joint.

The work must be clean, properly fluxed, and brought to the correct temperature. Parts should be held together securely during the operation and while cooling, to avoid internal fractures.

BRAZE WELDING

Braze welding is quite similar to brazing except that the joint between the parts is of a poorly fitted type. Brazing rod is actually flowed into the joint and built up until the joint has sufficient strength. See Fig. 8-11.

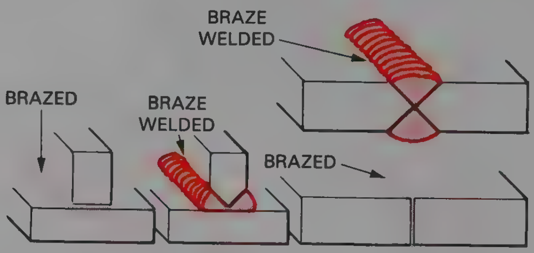


Fig. 8-11. Brazed and braze welded joints.

BRAZING ROD

Brazing and silver soldering (brazing with a filler rod of silver alloy) rods come in a wide variety of alloys. A regular bronze or manganese bronze rod is fine for average garage use on steel, cast iron, and malleable iron. Melting temperature is around 1,625°F (886°C) with a tensile strength (bonded to steel) of around 40,000 psi (275 800 kPa).

BRAZING FLUX

Numerous fluxes are available. Choose one compatible with the brazing rod being used. Rods are available with flux coatings. Flux in both powder and liquid form is commonly used. The uncoated bronze rod tip is heated and dipped into the flux. Enough will adhere to provide proper fluxing for a short while. The flux helps to remove oxides, and keeps oxides from forming during the brazing process.

SOURCES OF HEAT FOR BRAZING

A Bunsen burner, blowtorch, propane torch, oxyacetylene torch, and carbon arc will all produce sufficient heat for brazing and braze welding. Propane and oxyacetylene torches are well suited for the job and are generally available in the shop.

The acetylene torch, Fig. 8-12, is similar to a propane torch. A regulator is attached to a tank of gas, the tank valve is opened and set for the desired flow. As this torch utilizes oxygen from the air, only one tank

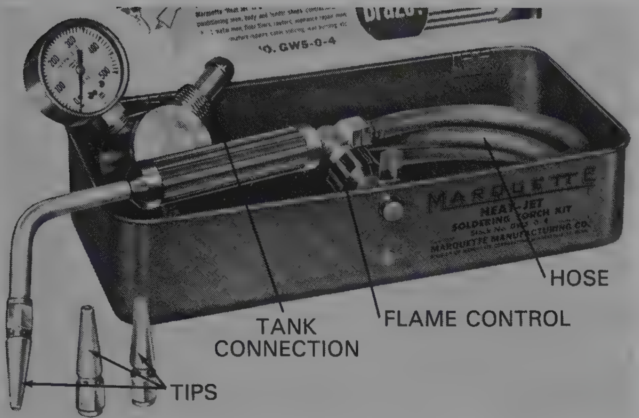

MARQUETTE
HEAT-JET
SOLDERING TORCH KIT
HOSE
TANK CONNECTION
FLAME CONTROL
TIPS

Fig. 8-12. Solder - braze kit. (Marquette)

(acetylene) is required. Several tip sizes are available.

A regular oxyacetylene outfit (uses a tank of oxygen and a tank of acetylene) is shown in Fig. 8-13. Oxyacetylene flame temperatures exceed 6,000°F (3 318°C). See Fig. 8-13.

BRAZING TECHNIQUE

Select a tip size appropriate to the work. The tip size chart, Fig. 8-14, will give you an indication of size in relation to metal thickness. Note the recommended gas pressures.

Adjust the torch to produce a neutral or slightly carburizing (excess acetylene) flame. Look at Fig. 8-15.

With the parts CLEAN, CLOSELY FITTED (ideal joint gap for brazing is .0015-.003 in. or 0.038-0.076

APPROXIMATE GAS PRESSURES FOR OPERATING AIRCO WELDING TORCHES

Tip No.	00	0	1	2	3	4	5	6	7
Mixer	00-1	00-1	1-7	1-7	1-7	1-7	1-7	1-7	6-10
Thickness of Metal (In.)	1/64	1/32	1/16	3/32	1/8	3/16	1/4	5/16	3/8
Oxygen Pressure (psi)	1	1	1	2	3	4	5	6	7
Acetylene Pressure (psi)	1	1	1	2	3	4	5	6	7

Fig. 8-14. Tip size and pressure chart.

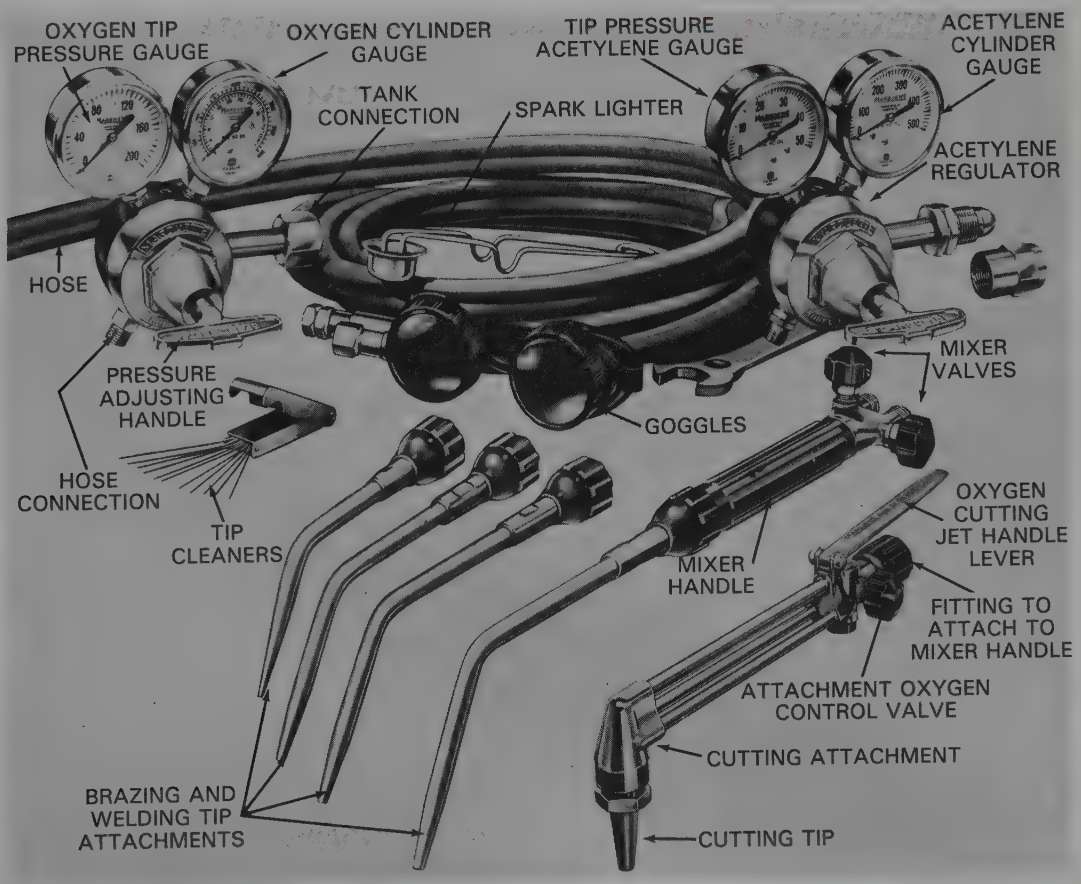

OXYGEN TIP PRESSURE GAUGE
OXYGEN CYLINDER GAUGE
TIP PRESSURE ACETYLENE GAUGE
ACETYLENE CYLINDER GAUGE
TANK CONNECTION
SPARK LIGHTER
ACETYLENE REGULATOR
HOSE
MIXER VALVES
PRESSURE ADJUSTING HANDLE
GOGGLES
HOSE CONNECTION
TIP CLEANERS
OXYGEN CUTTING JET HANDLE LEVER
MIXER HANDLE
FITTING TO ATTACH TO MIXER HANDLE
ATTACHMENT OXYGEN CONTROL VALVE
CUTTING ATTACHMENT
BRAZING AND WELDING TIP ATTACHMENTS
CUTTING TIP

Fig. 8-13. Oxyacetylene welding, brazing, and cutting outfit. (Marquette)

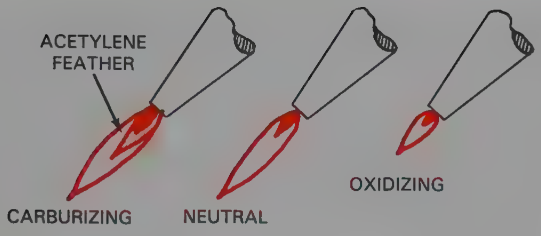


Fig. 8-15. Carburizing, neutral, and oxidizing flames.

mm), FLUXED, and FIRMLY HELD, apply heat to the joint. Use a brushing motion of the torch tip as shown in Fig. 8-16.

Watch the flux. When it starts to turn watery and clear, a little more heat will be sufficient. Touch the filler wire to the work. When the heat is correct, it will melt and tin the parts. Use the tip to guide the flow of metal (tinning action follows heat). Make sure the filler enters the joint full length and that it tins properly.

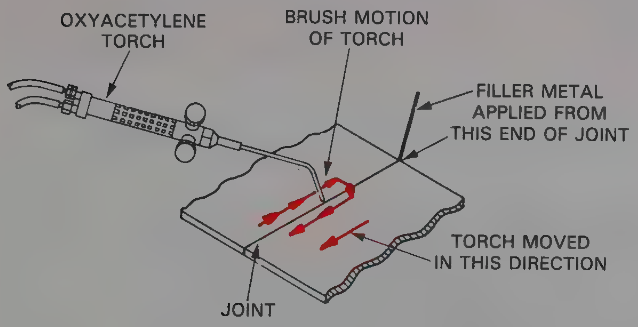

OXYACETYLENE TORCH
BRUSH MOTION OF TORCH
FILLER METAL APPLIED FROM THIS END OF JOINT
TORCH MOVED IN THIS DIRECTION
JOINT

Fig. 8-16. Heat joint prior to applying brazing material. When hot, start applying filler metal from one edge. Use the brushing motion of the flame to draw material along and into the joint. (AIRCO)

TIP DISTANCE AND ANGLE IS IMPORTANT

The distance the torch tip is held from the work affects the rate and extent of heating. Parts with a low melting point will require holding the tip further from the area to be brazed, Fig. 8-17.

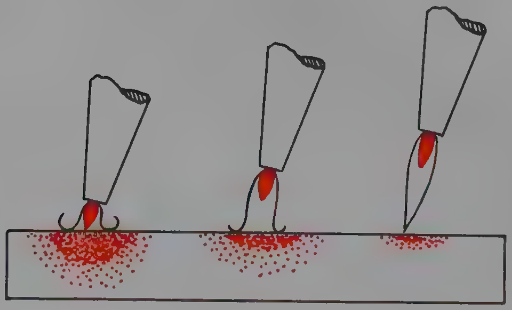


Fig. 8-17. Distance from tip to work affects heat transfer.

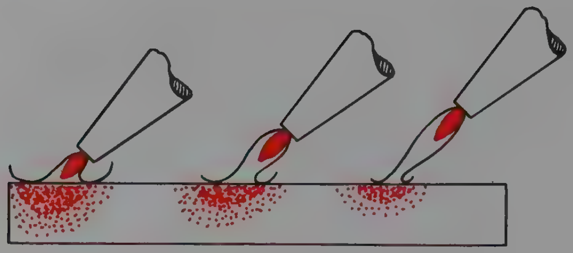


Fig. 8-18. Hold torch tip at an angle to work. (Brazing.)

By holding the tip at an angle, Fig. 8-18, the work is kept at brazing temperature with minimum danger of overheating. Note how the distance is varied to suit the work, while the angle is maintained.

KEEP TIP IN MOTION

Keep the tip in motion to spread the heat. If the flame is kept in one spot too long, overheating may result. A circular motion, Fig. 8-19, is desirable. The size of the circle should be decreased as the joint becomes heated. When brazing temperature is reached, the circles should be quite small. Using a zigzag motion during the application of the welding rod is also satisfactory.

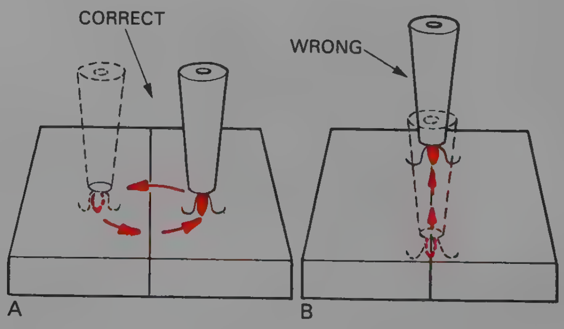


Fig. 8-19. Keep torch tip in motion. (Brazing.)

BRAZE WELDING TECHNIQUE

In braze welding, a groove, fillet, or slot is filled with nonferrous filler metal. The filler metal has a melting point below that of the base metal, but above 800°F (427°C). The filler metal is not distributed by capillary attraction.

The technique used for braze welding is similar to brazing. Once the brazing rod has flowed out and the parts have tinned, the heat should be carefully controlled. This allows the braze metal to build up to the desired thickness. The rod metal, as it is fed, must mix with that added before but must not cause the buildup to flow. See Fig. 8-20.

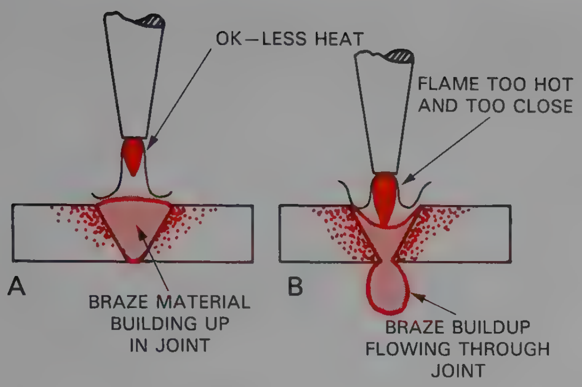

OK—LESS HEAT
FLAME TOO HOT AND TOO CLOSE
A
BRAZE MATERIAL BUILDING UP IN JOINT
B
BRAZE BUILDUP FLOWING THROUGH JOINT

Fig. 8-20. Braze welding. A—Correct. B—Too hot. Note how braze metal base sags.

RULES FOR GOOD BRAZING

1. Work must be clean and well fitted.
2. Use a tip and gas pressures in keeping with the job.
3. Use a neutral or slightly reducing (carburizing) flame.
4. Keep tip in motion.
5. Hold the tip at an angle to the work.
6. Heat may be controlled by changing distance from tip to work.
7. Braze metal should be suited to the job.
8. Use a good flux.
9. Braze metal must penetrate the joint and tin the surfaces.
10. Parts must be held in position and not disturbed until braze metal sets.
11. Avoid overheating.

GAS WELDING

Unlike brazing, welding is a fusion process. A portion of the metal of each part is melted. The melted areas flow together and upon cooling, form one solid part. Filler rod is often added during the process.

PREPARING THE JOINT

Thin metal, 1/32 in. (0.79 mm) or less, is often flanged to protect against heat warpage - A, Fig. 8-21. Parts not exceeding 1/8 in. (3.18 mm) may be welded by using a square edge-butt joint - B. When metal thickness ranges from around 1/8-3/8 in. (3.18-9.53 mm), a V-joint is used - C. Parts over 3/8 in. (9.53 mm) are usually prepared with a double V-joint - D, Fig. 8-21.

Both the joint and the immediate area must be cleaned of rust, scale, and paint.

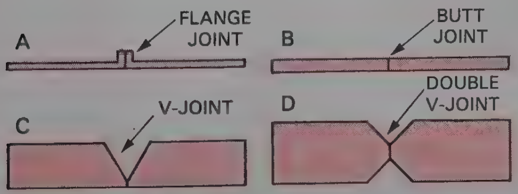


Fig. 8-21. Weld joint preparation in various thicknesses of metal.

USE NEUTRAL FLAME

Use a neutral flame for gas welding. The neutral flame will permit smooth, dense welds of high strength. There will be no foaming, sparking, or other problems.

A carburizing flame (excess acetylene) will cause molten metal to pick up carbon from the flame. This causes the metal to boil and upon cooling, to become brittle.

An oxidizing flame (excess of oxygen) will cause the metal to foam and send off a shower of sparks. The excess oxygen combines with the steel causing it to burn. The weld will be porous, weak, and brittle.

TIP SIZE SELECTION

Torch tip size must be suited to the job. Fig. 8-14 gives typical tip sizes and gas pressures for different metal thicknesses.

WELDING TECHNIQUE - BACKHAND METHOD

The tip should be directed back into the molten puddle, away from the direction of travel. The rod is held between the flame and weld. When the base metal

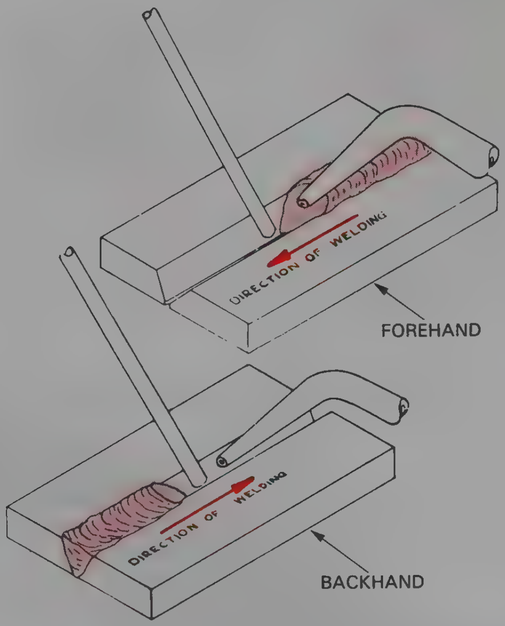


Fig. 8-22. Forehand and backhand welding techniques. (AIRCO)

(metal of parts being joined) melts and forms a puddle, the filler rod is added as the weld progresses. MELT THE ROD BY INSERTING THE END INTO THE PUDDLE. Do not hold the rod above the puddle and allow it to melt and drip in.

THE INNER FLAME CONE MUST NOT TOUCH EITHER THE ROD OR THE PUDDLE. Move the flame along the weld in a steady fashion, causing the base metal to reach the fusion state just ahead of the puddle. The welding rod can be moved from side to side, in small circles, or in half-circles. THE WELD SHOULD PENETRATE THROUGH THE JOINT. Fig. 8-22 shows both the forehand and backhand technique.

OXYACETYLENE CUTTING TORCH

The cutting torch finds many uses in the auto shop. In an oxyacetylene cutting torch, a preheating flame is maintained at the tip through small orifices or openings around the center orifice. The preheating flame is held close to the work at the point where the cut is to start. When the spot has been heated to a bright cherry red or hotter, depress the oxygen jet lever. When the stream of pure oxygen strikes the heated area, it will cut (burn) through the steel.

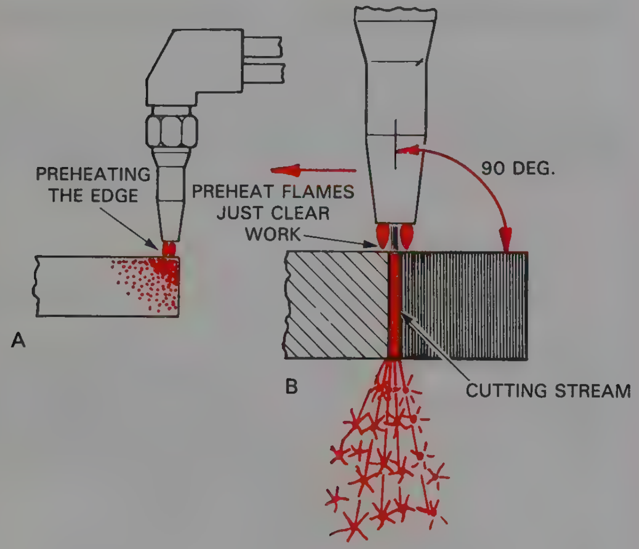

PREHEATING THE EDGE
PREHEAT FLAMES JUST CLEAR WORK
90 DEG.
A
B
CUTTING STREAM

Fig. 8-23. Hold the cutting tip at right angles to the work so the preheat flames just clear the work.

As soon as the cut starts, move the torch along the work. Move as rapidly as the cutting will allow. Keep the oxygen lever fully depressed. If the cutting action stops, release the oxygen lever. With the preheat flames (they burn continuously), preheat again. Hold the torch tip at right angles to the work with the preheat flames just above the surface. Refer to Fig. 8-23.

Note how the cutting torch removes a narrow kerf (cut) and how the molten metal (slag) is blown out from beneath the work. See Fig. 8-24.

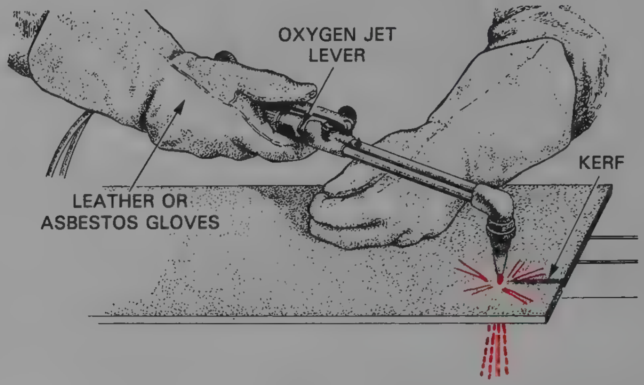

OXYGEN JET LEVER
KERF
LEATHER OR ASBESTOS GLOVES

Fig. 8-24. Torch cutting action. Note use of gloves. (Lincoln Electric Co.)

SETTING UP OXYACETYLENE EQUIPMENT

Keep both the acetylene and oxygen cylinders supported securely. The acetylene cylinder should be in the upright position to prevent loss of acetone

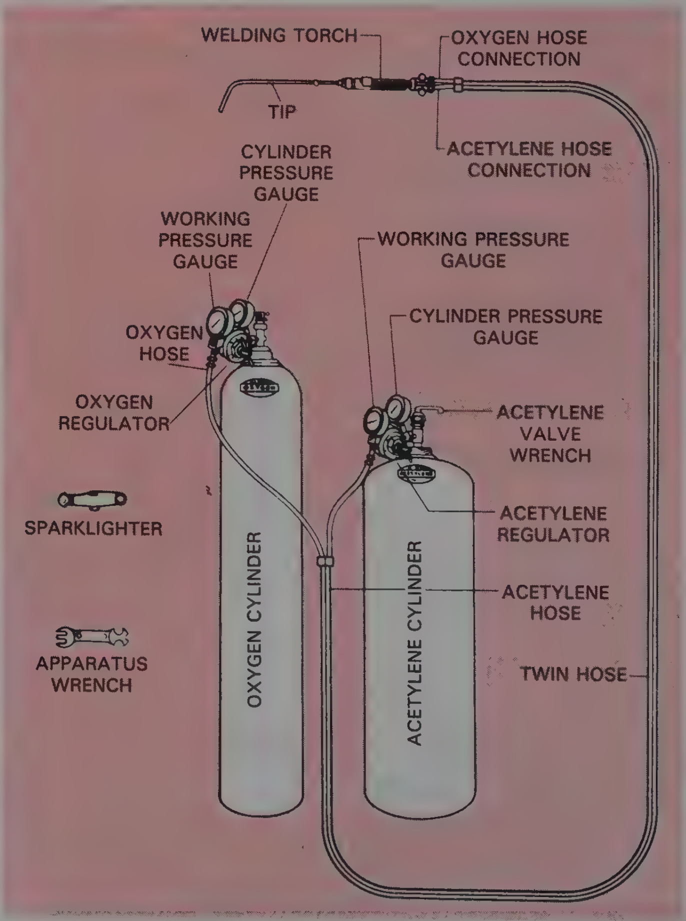

WELDING TORCH
OXYGEN HOSE CONNECTION
TIP
CYLINDER PRESSURE GAUGE
ACETYLENE HOSE CONNECTION
WORKING PRESSURE GAUGE
WORKING PRESSURE GAUGE
CYLINDER PRESSURE GAUGE
OXYGEN HOSE
OXYGEN REGULATOR
ACETYLENE VALVE WRENCH
SPARKLIGHTER
ACETYLENE REGULATOR
ACETYLENE HOSE
APPARATUS WRENCH
TWIN HOSE
OXYGEN CYLINDER
ACETYLENE CYLINDER

Fig. 8-25. Oxyacetylene welding setup. (AIRCO)

(acetylene cylinder is filled with acetone soaked porous filler material). Keep cylinders away from heat and flames. Protective tank valve caps must be in place when cylinders are stored. Mark empty tanks with letters MT. Fig. 8-25 illustrates how tanks or cylinders are attached to the welding setup.

REGULATORS

The oxygen regulator has a right-hand thread and the acetylene a left-hand thread. This prevents installing the regulators on the wrong cylinders.

The regulators reduce cylinder pressures to a controlled and useable amount. Figs. 8-26 and 8-27 illustrate typical regulators. Note the cylinder and hose fittings. The right-hand gauges read cylinder pressure. The left-hand gauges indicate tip operating pressure. Tip pressure is varied by adjusting the handles.

Before attaching regulators to cylinders, crack (open slightly) the valve on each cylinder a small amount for a second to blow out dust or other foreign material. Do not crack the acetylene near any open flames or near a welding operation. Attach the regulators to their respective tanks. Tighten gently. NEVER USE OIL ON REGULATORS. DO NOT HANDLE GAS WELDING EQUIPMENT WITH OILY OR GREASY HANDS. DO NOT WEAR OIL SOAKED CLOTHING. Oil, in the presence of pure oxygen, becomes highly flammable.

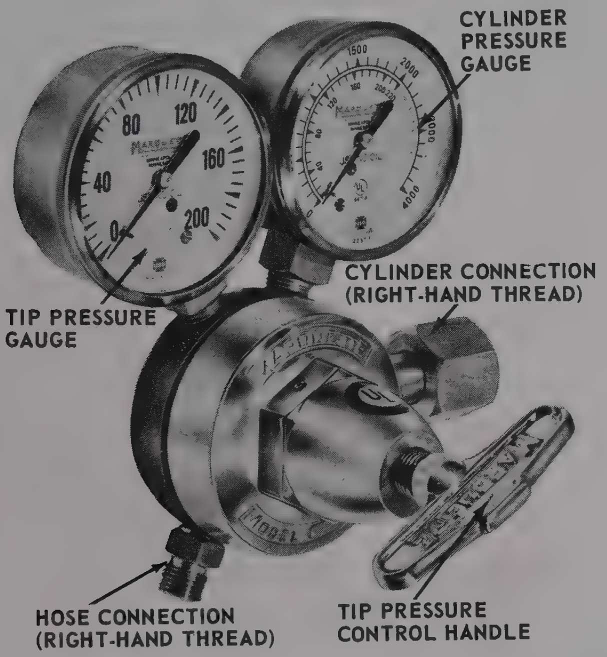

CYLINDER PRESSURE GAUGE
CYLINDER CONNECTION (RIGHT-HAND THREAD)
TIP PRESSURE GAUGE
HOSE CONNECTION (RIGHT-HAND THREAD)
TIP PRESSURE CONTROL HANDLE

Fig. 8-26. Typical oxygen regulator. Note high reading cylinder gauge.

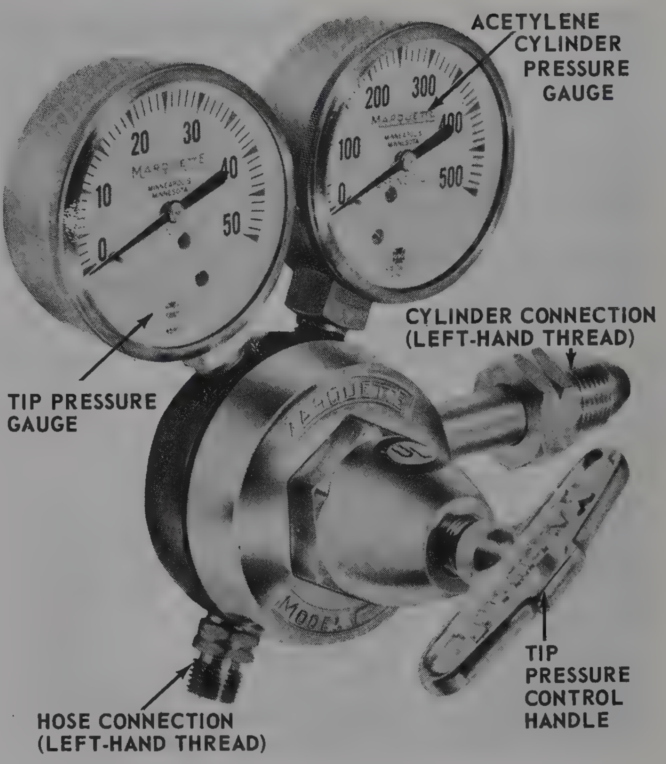

ACETYLENE CYLINDER PRESSURE GAUGE
CYLINDER CONNECTION (LEFT-HAND THREAD)
TIP PRESSURE GAUGE
TIP PRESSURE CONTROL HANDLE
HOSE CONNECTION (LEFT-HAND THREAD)

Fig. 8-27. Typical acetylene regulator. Note left-hand thread connections.

Back out the pressure control handle on each regulator (counterclockwise) until free.

ATTACH HOSE

Attach hoses to the regulators. The acetylene hose is normally red and the oxygen green. Acetylene fittings are left-hand threads while oxygen fittings are right-hand. When using the equipment, keep hoses away from hot sparks, flame, oil, and grease. Avoid kinking, and coil the hoses when finished working.

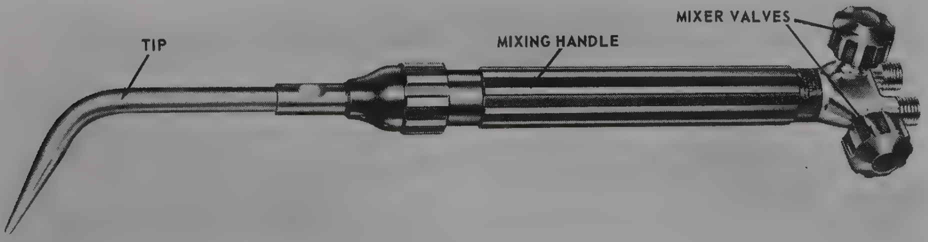

MIXER VALVES
TIP
MIXING HANDLE

Fig. 8-28. Torch mixing handle with a tip attached. (Marquette)

ATTACH TORCH MIXING HANDLE

The torch mixing handle should be attached to the hose end. Do not overtighten either mixing handle or regulator end hose connections. Where rubber O-ring seals are used, hand tightening is sufficient. Note the oxygen and acetylene mixing valves in Fig. 8-28.

ADJUSTING GAS PRESSURE

After installing the desired tip, MAKE SURE THE REGULATOR PRESSURE CONTROL HANDLES ARE BACKED (COUNTERCLOCKWISE) COMPLETELY OFF. THE TANK VALVES MAY THEN BE OPENED - VERY SLOWLY. Open the ACETYLENE VALVE about 1/4 to 1/2 TURN. Open the OXYGEN valve ALL THE WAY to prevent leakage around the valve stem. Leave the ACETYLENE WRENCH in place on the valve to facilitate an emergency shutoff - if required at any time.

SHUT the ACETYLENE mixing valve. OPEN the OXYGEN mixing valve. Turn the OXYGEN regulator handle in (clockwise) until the desired working pressure is obtained (read low pressure gauge). PURGE (clear the hose of air or other gases) the oxygen hose line by allowing oxygen to flow from the hose momentarily. SHUT off the oxygen mixing valve.

OPEN the acetylene mixing valve (oxygen valve off) and adjust acetylene regulator to desired pressure. Following purging, close acetylene mixer valve.

PURGING LINES IS VERY IMPORTANT. FAILURE TO DO SO CAN ALLOW ACETYLENE TO ENTER THE OXYGEN HOSE AND VICE-VERSA. THIS, OF COURSE, CREATES A COMBUSTIBLE MIXTURE INSIDE THE HOSE AND CAN CAUSE A FLASHBACK (FIRE BURNING INSIDE HOSE).

LIGHTING TORCH

Open the acetylene mixer valve a small amount while operating a scratcher or spark lighter in front of the tip. KEEP THE TIP FACING IN A SAFE DIRECTION. HAVE YOUR WELDING GOGGLES IN POSITION. See Fig. 8-29.

When the acetylene ignites, adjust the flame until it is hovering about 1/8 in. (3.2 mm) from the tip, A, Fig. 8-30. Immediately open the oxygen valve and adjust the flame. By starting with a carburizing flame, B, and slowly closing the acetylene valve, C, a neutral flame may be acquired, D. Watch the yellowish acetylene feather to tell when the neutral flame is reached, Fig. 8-30.

SHUTTING OFF TORCH

Close the acetylene mixer valve. The oxygen will blow out the flame at once. Then, shut off the oxygen mixer valve. When using this technique of shutting off the flame, make certain the acetylene valve is not leaking.

If you will be welding again within a few minutes, hang the torch up out of the way. If it will be some time before the torch is needed, drain the lines.

To drain the lines, shut off both the acetylene and oxygen cylinder valves. Open one mixer valve at a time until the low pressure gauge indicates there is no pressure left in that line. Back off the regulator adjuster handle. Close the mixer valve. Repeat on the other line.

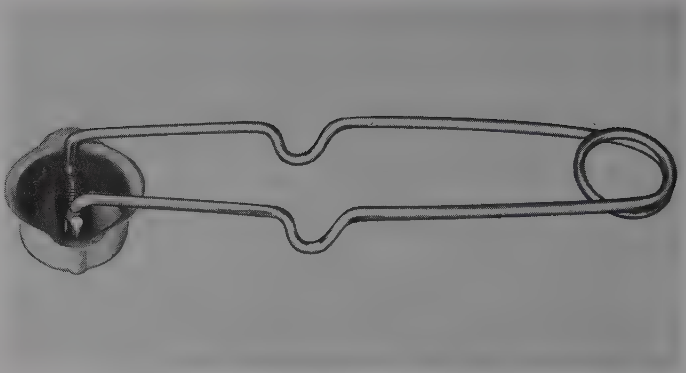


Fig. 8-29. Spark lighter. Squeezing handle moves a flint across a rough metal surface, producing a shower of sparks.

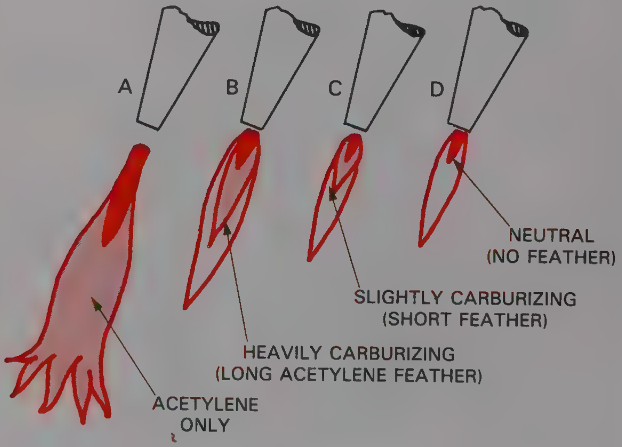

A
B
C
D
NEUTRAL (NO FEATHER)
SLIGHTLY CARBURIZING (SHORT FEATHER)
HEAVILY CARBURIZING (LONG ACETYLENE FEATHER)
ACETYLENE ONLY

Fig. 8-30. Adjusting to a neutral flame. Note acetylene "feather."

LIGHTING CUTTING TORCH

Set regulators to give required pressure. Close the cutting attachment oxygen valve. Open the mixer oxygen valve all the way. Open the acetylene mixer valve and light the torch. Open attachment oxygen valve and adjust preheat flames to neutral. Depress oxygen jet lever and if preheat flames are altered, readjust. These directions are for a cutting attachment - shown in Fig.

8-13. If another cutting torch is used, follow the manufacturer's instructions.

BASIC SAFETY RULES FOR OXYACETYLENE EQUIPMENT

1. Wear protective goggles.
2. Wear protective gloves and clothing.
3. Keep all oil and grease away from equipment.
4. Never use equipment with greasy hands or when wearing greasy garments.
5. Have ample ventilation.
6. Do not cut, weld, or braze fuel tanks until special precautions have been taken.
7. Do not work in an explosive atmosphere.
8. Always have a fire extinguisher on the job.
9. Open cylinder valves slowly.
10. Maintain good hoses and fittings.
11. Purge lines before lighting.
12. Never use defective regulators.
13. Inspect hose for damage following a flashback.
14. Never try to repair hose with tape. If a hose leaks, discard it.
15. Stand to one side of regulators when opening cylinder valves.
16. Open acetylene cylinder valve no more than ONE turn.
17. Never use acetylene at pressures exceeding 15 psi (103 kPa).
18. When adjusting either oxygen or acetylene pressures, make certain the other mixer valve is closed. This will prevent flashbacks.
19. Hold torch in a safe direction when lighting.
20. Know what you are cutting or welding. Some coatings produce deadly gases when heated.

THERE ARE MANY MORE SPECIFIC SAFETY RULES. STUDY A BOOKLET ON SAFE PRACTICES FROM ONE OF THE COMPANIES HANDLING GAS WELDING EQUIPMENT. HAVE AN EXPERIENCED OPERATOR ASSIST YOU UNTIL YOU HAVE MASTERED SETTING UP, LIGHTING, AND USING EQUIPMENT SAFELY.

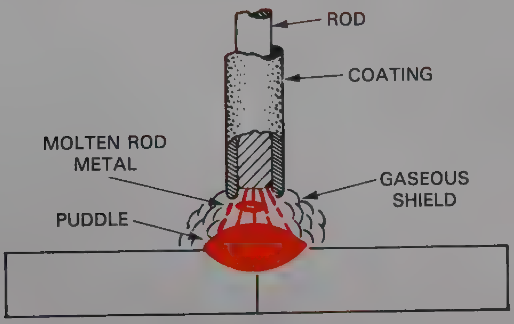


Fig. 8-31. Using the electric arc for welding. Note molten globule traveling from rod to puddle.

ARC WELDING

Arc welding utilizes the intense heat (6,000-10,000°F or 3 318-5 542°C) generated by an electric arc between the end of the welding rod and the work. Both the base metal and filler rod quickly reach the fusion state. As the work puddles, the rod end melts and flows into the molten base metal. The arc force actually causes the molten globules of rod metal to travel through the arc to the puddle. This allows the arc welder to be used for overhead welding. See Fig. 8-31.

TYPE OF MACHINE

Basically, an arc welding machine may be an AC (alternating current) or DC (direct current) machine. Combination AC - DC machines are also available.

The AC or AC - DC machine is generally a power transformer that alters the incoming 220-440 volts (utility line voltage) to a low voltage, high amperage current for welding. A typical AC - DC machine is pictured in Fig. 8-32.

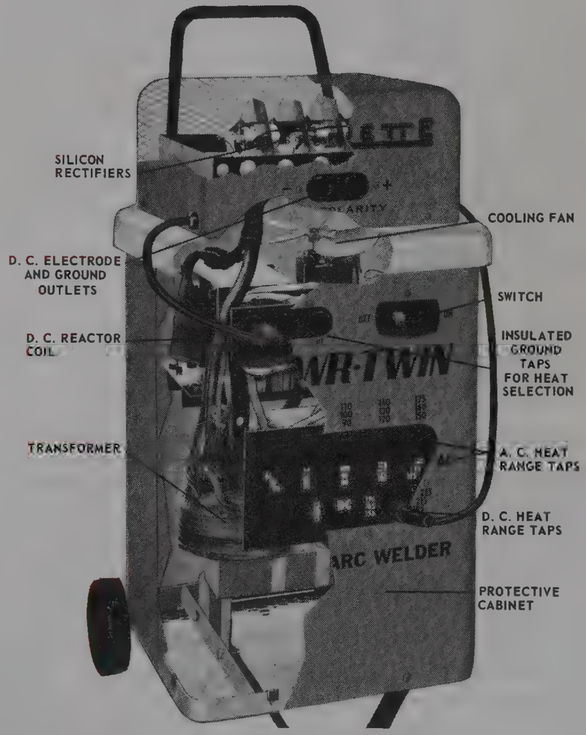


Fig. 8-32. Combination AC - DC arc welding machine. (Marquette)

The DC machine is usually motor (electric or gas engine) driven. Both types have certain advantages and disadvantages. Machines are rated by maximum output in amperes. The higher the output, the heavier welding the machine will perform.

POLARITY

Two common terms used in DC arc welding are STRAIGHT POLARITY and REVERSE POLARITY. Reverse polarity means the current is traveling from the work, up through the arc to the rod and rod holder. Straight polarity means the current travels from the rod holder (often called a stringer) through the rod, across the arc, and to the work. For a straight polarity hookup, merely plug (unless a polarity switch is used) the rod holder cable into the hole marked with the straight (negative) symbol (−). For a reversed polarity hookup, plug the rod holder cable into the crossed (positive) symbol (+).

Polarity is not a factor in AC welding as the current is constantly reversing itself 60 times per second. See Fig. 8-33.

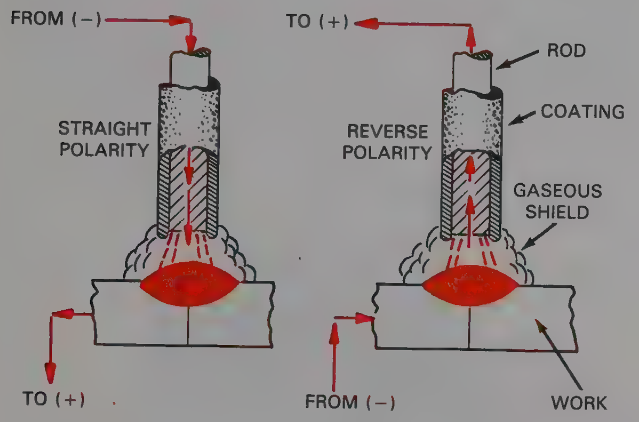


Fig. 8-33. Current travel with straight and with reversed polarity.

WELDING SETUP

Study Fig. 8-34. This setup shows the welding machine, rod holder, ground clamp, and connecting cables.

ROD SIZE

Welding rods (electrodes), usually 12-14 in. (305-356 mm) in length, are available in many sizes (diameters). They start at 1/16 in. (0.063 mm). For general auto shop use, an assortment in sizes 1/16, 3/32, 1/8, 5/32, and 3/16 in. (0.063, 0.094, 0.125, 0.156, and 0.188 mm) will be adequate.

ROD TYPE

Welding rods are usually coated to provide a gaseous shield around the arc. This shield helps remove impurities and prevents oxidization. A special self-starting, self-spacing rod is offered. The coating is kept in contact with the work thus maintaining the correct distance from rod to work.

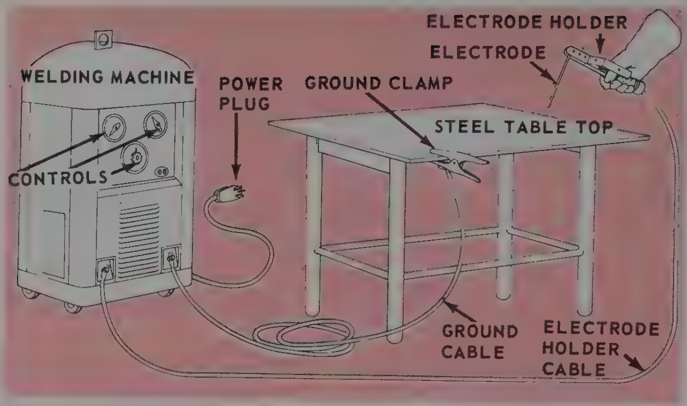


Fig. 8-34. Typical arc welding setup. (Lincoln Electric Co.)

Rods are available for welding mild steel, carbon steel, cast iron, cast iron to steel, aluminum, and other metals. Select a rod suited to the welding job - both in diameter and rod material.

PROTECTIVE EQUIPMENT

Always wear a welding helmet to protect your face and eyes. A helmet has a dark glass window that will allow you to watch the blinding arc without eye strain or damage.

Fig. 8-35 shows a welder using protective equipment.

Leather or asbestos gloves should be used to protect your hands from radiation and from spatter (flying bits of molten metal) burns.

Clothing must be heavy and of a hard finished cotton (no wool or synthetics) to shed sparks and spatter without igniting. Overhead and horizontal welding can cause a rain of hot spatter to fall on your arms and shoulders. In these cases, a leather jacket should be worn. See Fig. 8-35. Pockets must not be open to receive red hot drops. Shoes must have leather tops and should be high enough to prevent the entry of sparks. Do not wear a ring because it is possible to ground the ring between the work and the rod. With heavy welding currents, this can heat the ring to a high temperature very quickly.

CAUTION!

Your eyes can suffer severe burn damage from rays produced during arc welding. NEVER WATCH THE ARC (EVEN FOR A SECOND) WITHOUT THE USE OF A HELMET OR FACE MASK. Never strike an arc when another person is standing nearby unless the person is wearing protective goggles. Eye burns are "sneaky" in that the pain does not immediately follow the exposure.

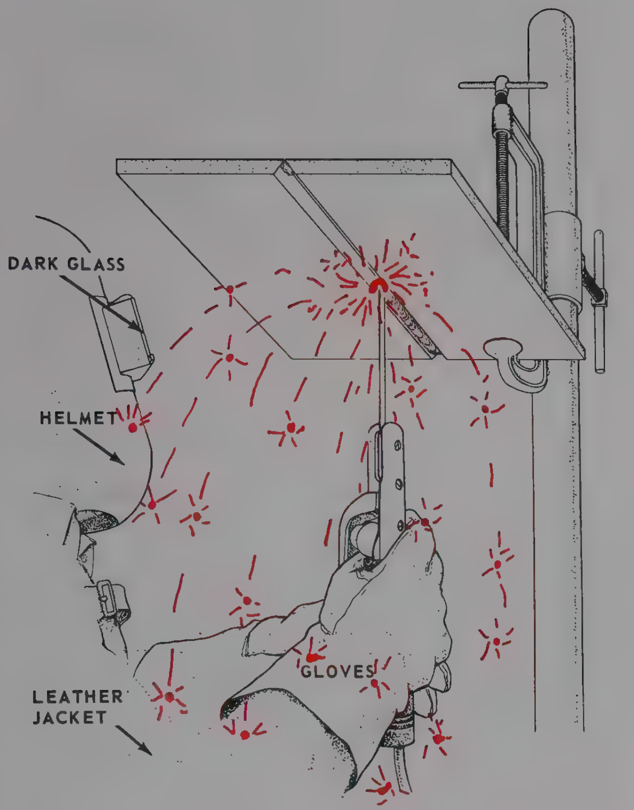


Fig. 8-35. Protective equipment is a must.

SETTING UP TO WELD

Attach the ground clamp securely to a spot on the work that is free of paint, rust, etc. After selecting the correct size and type of rod, set the machine as recommended. Insert a rod in the rod holder. The holder jaws must grip the uncoated end to provide an electrical path. Turn the machine on and strike an arc.

STRIKING AN ARC

Strike the end of the rod against the work with a short, scratching motion. When the arc forms, pull the rod away the recommended distance. Look at Fig. 8-36.

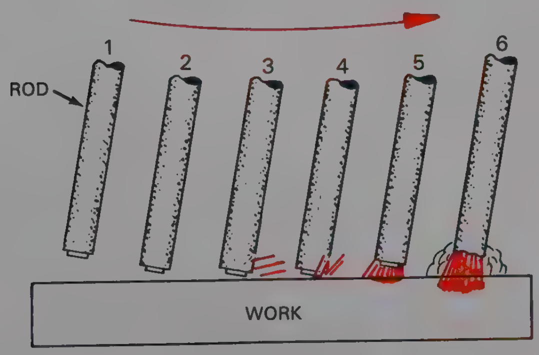


Fig. 8-36. Striking an arc.

WELDING

When the base metal puddles (melts), move the rod forward slowly. Some rods may be held steady while others require a whipping motion. When whipping, move the rod out of the molten puddle until the puddle starts to freeze (solidify and turn from a shiny wet look to a dull sheen). Then, immediately move it part way back into the puddle. When the puddle is fluid again, hold the rod in place for a split second. Then, whip it out again. Repeat this process. Viewed from the top, the whipping process can form either a straight line or a C shape, depending on the need.

Whipping is handy in controlling burn-through in thin metal, or when working with wide gaps. The rod should be held at right angles to the work with the top of the rod tilted 5-15 deg. toward the direction of travel. See Fig. 8-37.

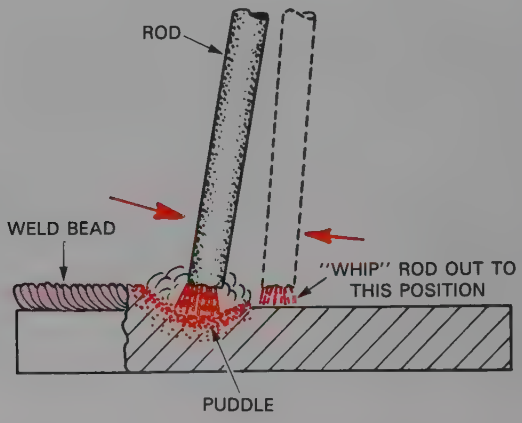


Fig. 8-37. Welding with a whipping motion of the electrode (rod).

Whipping should be done by flexing the wrist. The whipping motion produces a series of circular ridges along the top of the weld. At first, it may be difficult to maintain correct arc length. Continued practice will enable you to develop skill. Always use recommended machine settings.

Occasionally, a weaving motion will be required. This will help to bridge wider gaps and will deposit weld metal over a wider surface. This is shown in Fig. 8-38.

Study Fig. 8-39. It pictures a series of welds. All welds were made with the same type and size electrodes. Machine settings and welding speeds were varied to demonstrate the effects.

The sound of the arc is helpful in determining when it is the correct length and of the proper heat. A good arc has a steady "bacon frying in the pan" sound. A short arc will make popping noises and will tend to cause the rod to stick to the work. Excessive arc length

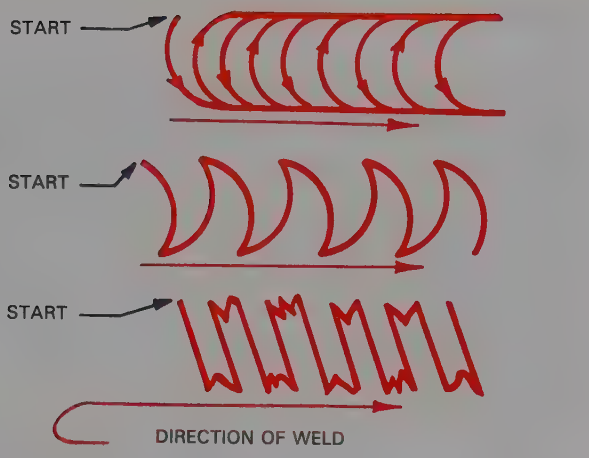


Fig. 8-38. Weaving patterns for arc welding. (Marquette)

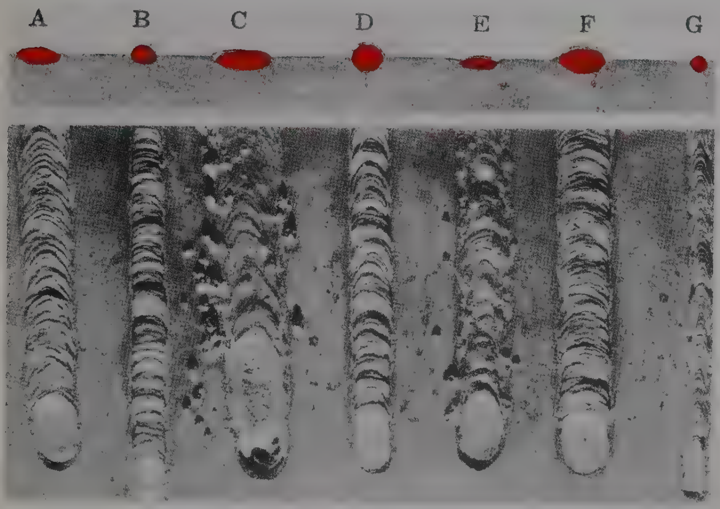


Fig. 8-39. Effects of various machine settings, arc lengths, and welding speeds. Rod type and size remained constant. A—A good, smooth weld. Note even whip marks and lack of spatter. B—Machine settings too low. Weld is narrow with little penetration. It is piled high. C—Machine settings too high. Note excessive width, blowholes, and heavy spatter. D—Settings OK but arc too short. E—Settings OK but arc too long. F—Settings OK, arc OK, but speed too slow. G—Arc OK, settings OK, but speed too fast. (Lincoln Electric Co.)

will cause a high, humming noise with a lot of spatter. The arc also tends to go out.

MANY TYPES OF WELDS

Weld position and work set-up can be quite varied. This will require skill in flat, horizontal, vertical, and overhead welding. See Fig. 8-40.

WORK SHOULD BE CLEAN

Despite the fact that a good welder can run a bead through rust, paint, and moisture, all weld areas should be dry and clean. The weld will go faster, look better, and be stronger.

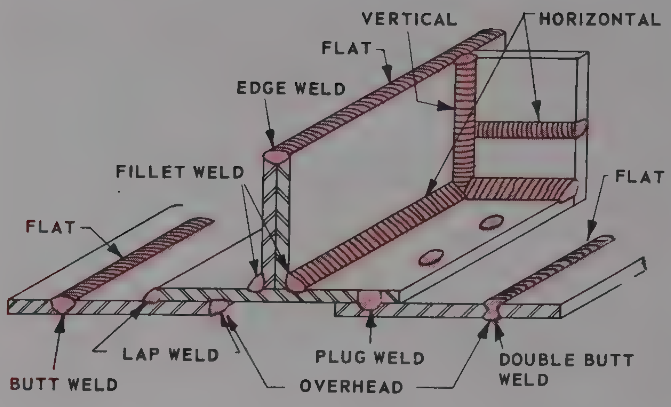


Fig. 8-40. Different welds and welding positions.

Chip the slag (brittle coating left on weld from rod coating material) from the bead. Use a wire brush to complete the cleanup job before making the next pass (bead). Some thick parts require a number of passes. If the slag is not removed, the joint may be full of slag inclusions (particles) and blowholes (air pockets).

WHEN CHIPPING OR WIRE BRUSHING, WEAR PROTECTIVE GOGGLES. YOUR HELMET MAY BE DESIGNED TO TIP UP THE DARK GLASS AND PERMIT YOU TO LOOK THROUGH THE CLEAR GLASS. GETTING A PIECE OF SLAG IN YOUR EYE CAN BE SERIOUS.

TIG AND MIG WELDING

There are basically two types of shielded gas welding: tungsten-inert-gas (TIG) and metal-inert-gas (MIG). The welding takes place inside an inert gas (helium, argon, neon, krypton) shield. This gas shield is used to protect the puddle of molten metal from contamination by nitrogen and oxygen in the air.

These two welding techniques are designed primarily for repairing aluminum, copper, and other nonferrous (contains no iron) metals. They can also be used to weld ferrous (contains iron) metals.

A TIG welding process is illustrated in Fig. 8-41. Notice the "filler wire" position. A MIG process is shown in Fig. 8-42. Note that the "filler wire" is passed through the center of the gas nozzle as welding takes place.

BASIC SAFETY RULES FOR ARC WELDING

1. Never look at the arc unless wearing a suitable helmet or face shield.
2. Do not permit bystanders, unless they are wearing protective gear.
3. Wear goggles when chipping or wire brushing.
4. Wear protective clothing and gloves.
5. Make certain the welding machine is properly grounded.

6. Never weld while standing in water or on damp ground.
7. Never carelessly strike an arc on a car gas tank, or on compressed gas cylinders.
8. Do not strike arc on automobile brake lines, gas lines, or other potentially dangerous parts.
9. Have adequate ventilation.
10. Be careful when welding metal with coatings such as zinc, cadmium, and beryllium. The fumes may be deadly.
11. Disconnect the welding machine before attempting any repairs.

GENERAL CAUTIONS

1. Do not adjust machine settings or attempt to change polarity while the machine is under load (welding). This will damage the switch contacts.
2. Keep the ground clamp and tool holder apart. Never start the machine until certain the rod holder is not touching the work.
3. Keep cables tight in the sockets, clamp, and rod holder. This will prevent excessive resistance and overheating.
4. Protect paint, glass, and upholstering from hot spatter.
5. Keep cables coiled when not in use.
6. Do not attach ground clamp to bumpers or other chrome parts. Any looseness will cause arcing that will pit the chrome.

ALWAYS CHECK FOR PART CRACKING

Many parts of the automobile, such as engine blocks, pistons, crankshafts, gears, axles, wheel spindles, can crack during service.

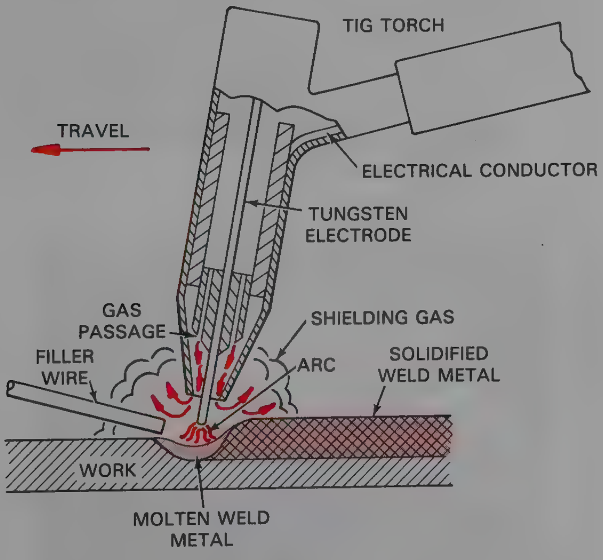

TIG TORCH
TRAVEL
ELECTRICAL CONDUCTOR
TUNGSTEN ELECTRODE
GAS PASSAGE
SHIELDING GAS
FILLER WIRE
ARC
SOLIDIFIED WELD METAL
WORK
MOLTEN WELD METAL

Fig. 8-41. Tungsten-inert-gas (TIG) welding process. Note gas exiting torch nozzle and creating a protective shield. (Lincoln Electric Co.)

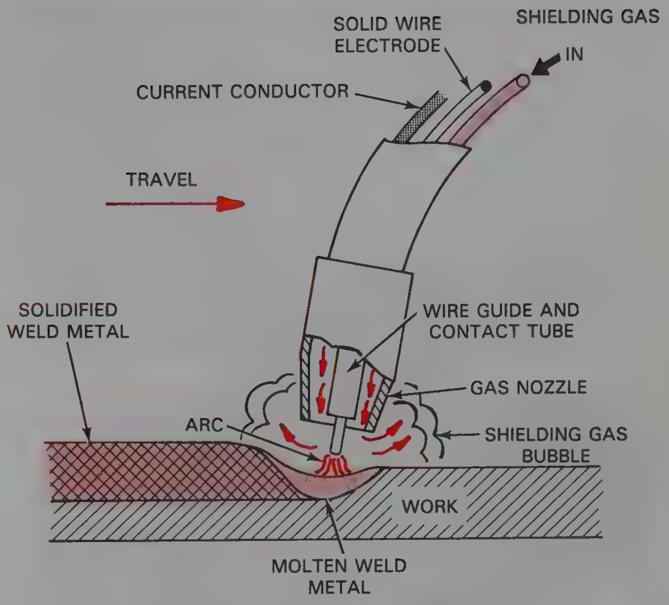

SOLID WIRE ELECTRODE
SHIELDING GAS IN
CURRENT CONDUCTOR
TRAVEL
SOLIDIFIED WELD METAL
WIRE GUIDE AND CONTACT TUBE
GAS NOZZLE
ARC
SHIELDING GAS BUBBLE
WORK
MOLTEN WELD METAL

Fig. 8-42. Metal-inert-gas (MIG) welding procedure. Note shielding gas protective bubble and solid wire electrode being fed through nozzle. (Lincoln Electric Co.)

During overhauls, parts should be thoroughly cleaned and visually inspected for signs of cracking. Pay particular attention to such areas as cylinder head valve ports, cylinder walls, block water jackets, and pistons.

Critical parts such as wheel spindles, steering gears, and axles should be checked with special detection equipment.

Cracks or fractures may be grouped in three types:

1. Cracks plainly visible to the eye.
2. Cracks so fine as to be invisible without detection equipment.
3. Internal cracks that do not reach the surface.

CRACK DETECTION METHODS

There are a number of techniques used to check for the presence of cracking including X-ray, magnetic, fluorescent, dye penetrants, and combinations of these techniques. The X-ray technique requires expensive equipment and is only used in large specialty shops.

MAGNETIC FIELD WITH IRON POWDER

A powerful magnet (can be a permanent or an electromagnet) is placed across an area suspected of containing a crack. A fine iron powder is then dusted over the area. The metal under the feet of the magnet becomes heavily magnetized. A crack will interrupt or break this magnetic field enough to cause the iron powder to collect along the crack. The magnet should be moved into different positions. The process works best when the crack is at right angles to the magnetic field.

Fig. 8-43 illustrates the use of a powerful permanent magnet. Note the crack (in color) that has been exposed by iron powder collecting along the entire length. The poles of the magnet are at right angles to the crack.

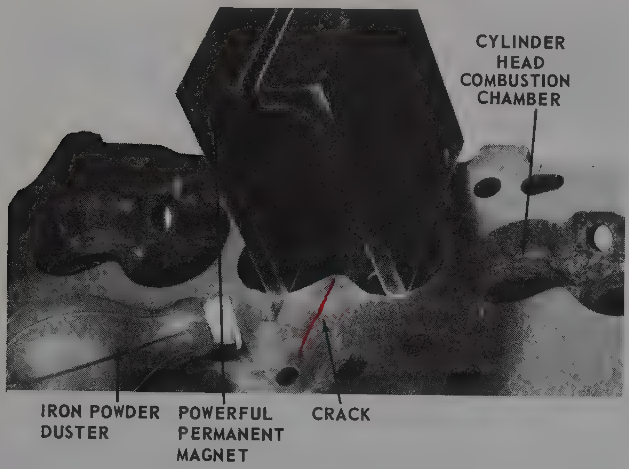


Fig. 8-43. Crack in cylinder head is exposed through use of a powerful magnet and iron powder. (Storm-Vulcan)

MAGNETIC FIELD WITH FLUORESCENT FERROMAGNETIC PARTICLES

This method also requires that a strong magnetic field be set up in the part. A special solution that contains fluorescent ferromagnetic particles is then sprayed on the area to be tested. Fig. 8-44 shows a crankshaft being checked for cracks. Note the ring magnet and black light lamp.

As with iron powder, the ferromagnetic particles are attracted to and held along the crack line. When exposed to a black light (invisible ultraviolet rays), the particles packed along the crack line will glow white while the remainder of the part will remain blue-black. A black light (ultraviolet rays) is not harmful to skin or eyes.

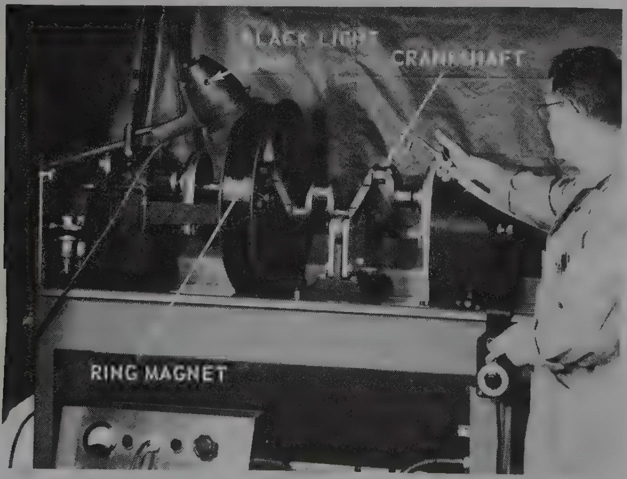


Fig. 8-44. Checking crankshaft for cracks.

The crankshaft in Fig. 8-45 has two cracks along the journal edges. Note that the cracks are clearly visible under black light.

NOTE: Magnetic crack finding will work ONLY ON MATERIALS THAT MAY BE MAGNETIZED. Nonferrous metals, such as copper, aluminum, and bronze, cannot be magnetized. If in doubt, apply a magnet to the questionable metal. If the magnet sticks to the metal, it can be checked magnetically.

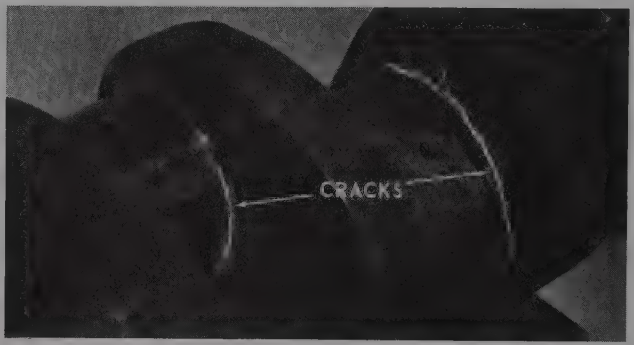


Fig. 8-45. Cracks in crankshaft are plainly visible under black light. (Magnaflux)

FLUORESCENT PENETRANT

This method involves the use of a special fluorescent penetrant (liquid that readily enters even finest cracks). The area to be checked is first cleaned with a patented cleaner. See Fig. 8-46. Then, the fluorescent penetrant is sprayed over the area, Fig. 8-47. A small amount of cleaner is sprayed on the gear and the excess penetrant wiped off with a clean cloth, Fig. 8-48. The part is then sprayed with a developing solution. The developer will draw the penetrant to the surface of any cracks, Fig. 8-49.

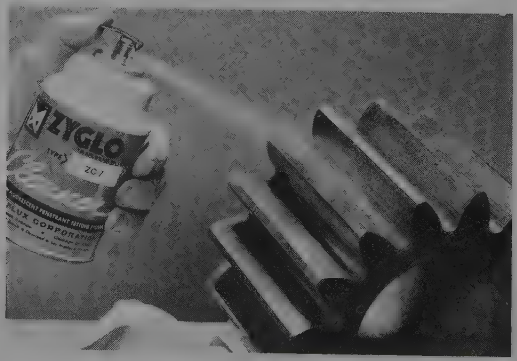


Fig. 8-46. Cleaning section of large gear prior to application of fluorescent penetrant.

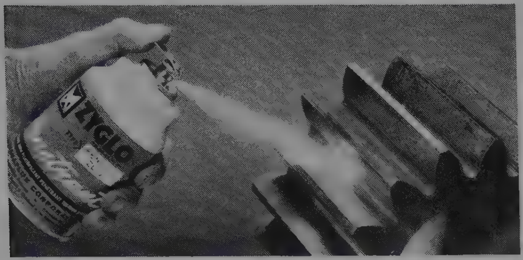


Fig. 8-47. Applying fluorescent penetrant. (Magnaflux)

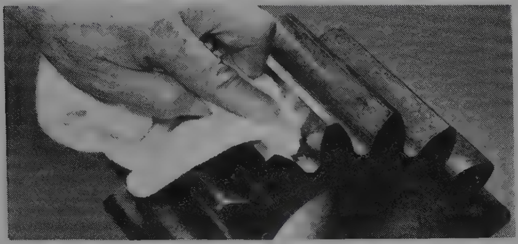


Fig. 8-48. Removing excess penetrant.

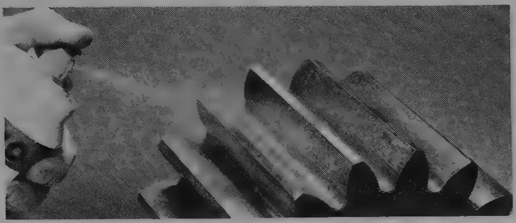


Fig. 8-49. Applying developer solution.

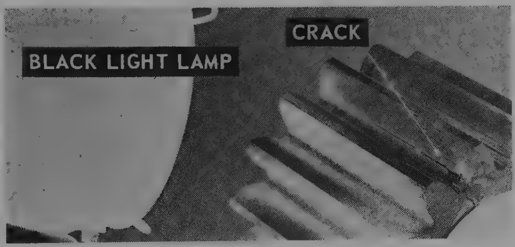


Fig. 8-50. Examining part under black light. Note crack.

The gear is examined under a lamp that emits black light. If any cracks are present, the developed penetrant will glow quite visibly, Fig. 8-50.

DYE PENETRANT

Dye penetrant, when exposed to a developer, will show as a bright red stain line against a whitish background. The part is cleaned, penetrant applied, surplus penetrant removed, and developer sprayed on. Note the red stain lines indicating cracks between the gear teeth in Fig. 8-51.

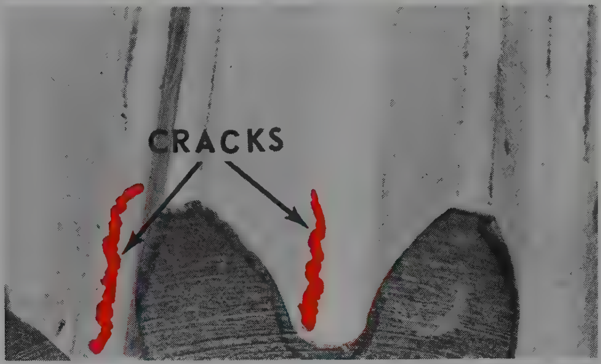


Fig. 8-51. Dye penetrant exposed cracks in this gear.

NOTE: The penetrant methods will work on both ferrous and nonferrous materials.

CRACK REPAIR

Cracks in the cylinder head or block can often be repaired by either brazing, welding, or pinning. Sometimes solder can be used on water jacket cracks.

The use of threaded pins is quite popular because no heat is required (no chance of warpage). IF THE PINS ARE TO BE EFFECTIVE, THEY MUST REACH SLIGHTLY PAST THE ENDS OF THE CRACK. If they do not reach the ends, the crack may continue to lengthen. Further cracking can generally be halted by drilling a hole at the end of the crack. See Fig. 8-52.

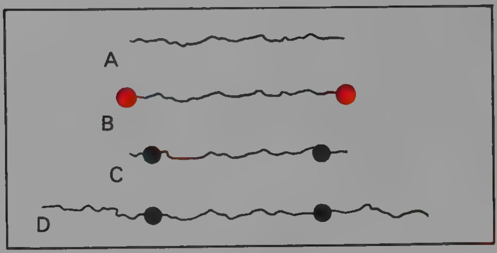


Fig. 8-52. A—Note crack. B—Holes have been drilled at the very ends. This prevents further cracking. C—Hole drilled in from the ends. D—This allows cracking to continue.

Use special, threaded, taper pins designed for crack repair. Start by drilling and tapping a hole that centers on the crack line, just beyond the end of the crack. Thread the correct size pin (pin may be coated with special heatproof sealant if desired) into the hole. When tight, notch the pin, about 1/8 in. (0.125 mm) above the casting. Use a sharp chisel. Twist off the excess. In some cases, a hacksaw may be used to cut the pin.

Drill and tap for the next pin so the hole just cuts through the threads of the first pin. Install plug and twist off excess. Repeat this process until the full length

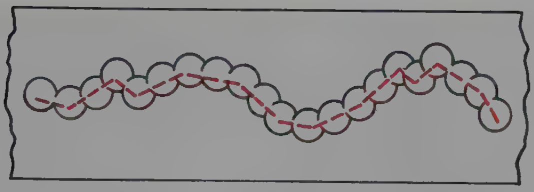


Fig. 8-53. Crack repaired by pinning. Each pin should slightly overlap preceding pin. Broken line indicates crack line.

of the crack is pinned. EACH PIN MUST CUT PART WAY INTO THE PRECEDING PIN. See Fig. 8-53.

If steel pins are used, they should be lightly peened.

Grind pins nearly flush with work and finish with a clean, sharp mill file. If the area cannot be filed, grind flush.

When a crack passes over an edge (such as across head and down into combustion chamber) insert pins in the order shown in Fig. 8-54.

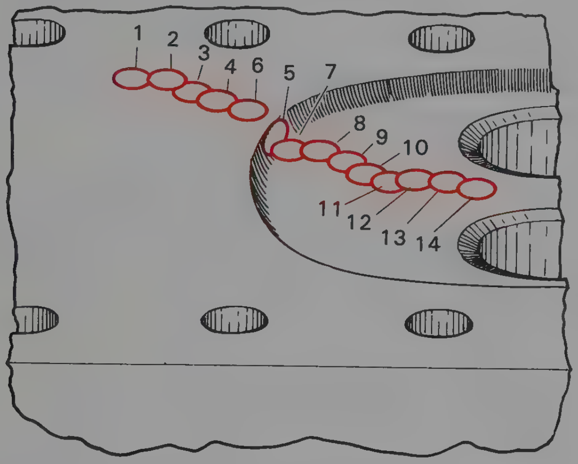


Fig. 8-54. Insert pins in the order shown. Pin 6 will lock pin 5 in place in case pin 7 does not properly overlap.

SUMMARY

Solder is a mixture of lead and tin in varying amounts. Joints to be soldered must fit well. Solder has little strength if the parts are far apart. Wire solder, with flux-filled center core, is desirable.

Flux (organic, acid, and rosin) helps remove oxides and also prevents the formation of oxides while soldering. Be sure to use solder with ROSIN core ONLY on ELECTRICAL work.

Keep the soldering iron clean and well tinned. Use an iron large enough for the job.

The joint to be soldered must be clean and dry. Lay the flat tip of the iron against the work and apply wire solder where the iron and work contact. Solder must run and tin freely. Do not move work while it is cooling.

Brazing takes place above a temperature of 800°F (427°C). The work must be clean. Flux work and heat until brazing rod melts when in contact with the parts. Capillary action will draw the brazing material into the joints. Do not overheat.

Braze welding requires tinning the work with braze material. Then, build up to fill joint irregularities and provide strength. Bronze brazing rod may be used on cast iron, malleable iron, and steel. Either a propane or an oxyacetylene torch may be used.

Choose a torch tip appropriate for the work. Set the gas pressures as recommended by the torch manufacturer. Use a neutral flame (approximately one-to-one mixture of acetylene and oxygen) to slightly carburizing flame (one-to-one mixture is varied to give excess of acetylene). Hold the tip at an angle to the work. Vary the distance from tip to work as needed. Keep tip in motion to avoid localized overheating.

Gas welding involves fusion (melting and mixing) of the metals to be joined. The work should be clean and dry. Thick metals should be beveled. Select a torch tip of the size recommended by the manufacturer. Set gas pressures for selected tip. Adjust to a neutral flame.

When welding, keep the inner flame from touching either filler rod or puddle. Bring the work to the molten state and, if required, add filler rod. The weld must penetrate the work and should be solid and free of slag and blowholes.

Cutting is fast and easy with oxyacetylene cutting torch.

Follow all safety precautions in setting up equipment, lighting torch, and in welding.

Arc welding is fast and applies a minimum amount of heat to the work. Although the arc temperature is high, the welding process is so rapid that the work remains relatively cool. This helps control warpage.

Select appropriate rod size and type.

Adjust machine to correct polarity and current settings. Tip the top of the rod in the direction of travel (5-15 deg.). A whipping motion will help control the heat, direction, and penetration of the weld.

The bead should be smooth, even, with good penetration, and should be free of slag and blowholes. Remove slag from a bead before welding another pass over the original bead.

Follow all safety rules in setting up and operating.

Tungsten-inert-gas (TIG) and metal-inert-gas (MIG) are two types of shielded gas welding. The material being joined is protected from contamination by an inert gas shield. These welding techniques are used for nonferrous and ferrous metals.

Cracks can be detected by using a magnetic technique involving iron powder or fluorescent liquid, or by using either dye or fluorescent penetrants.

Cracks in engine blocks and heads can often be repaired by pinning. Use tapered, threaded pins. Pins should overlap slightly and must run full length of the crack.

MANY SKILLS ARE REQUIRED

The top-level mechanic, capable of handling the many phases of automotive repair, must have a number of talents. Numerous basic skills are required, not all of which are commonly associated with auto work.

Being a successful mechanic involves much more than mere disassembly, inspection, part replacement, and reassembly. Quite often, parts must be rebuilt, altered, adapted, or welded. To cope successfully with all these demands, the mechanic must have some knowledge of machine shop, welding and brazing, sheet metal work, electricity, and other fields.

When you, in your work as a mechanic, meet a situation that calls for skills you do not possess, DEVELOP THEM. Night school, extension courses, on the job training, books, manuals, trade journals, and magazines, all provide opportunities for you to learn.

Remember that each year sees changes in design, new units, new service techniques, new service equipment, and new materials. Be sure to develop a regular program of reading and study. Then, you will always be UP-TO-DATE. It will pay big dividends.

KNOW THESE TERMS

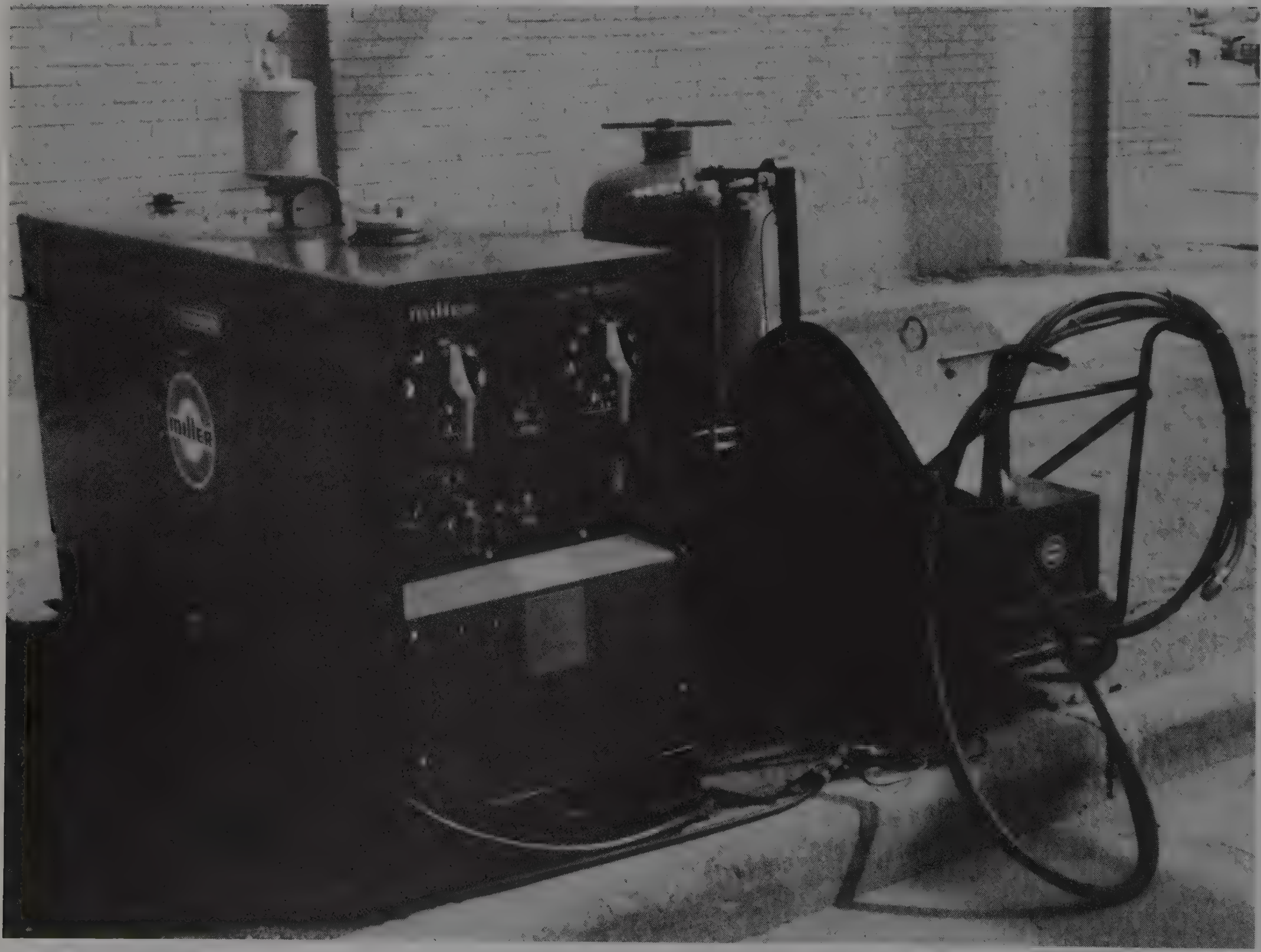
Soldering, Melting point, Amalgamate, Plastic range, Soldering flux, Soldering iron, Iron tinning, Sweating, Brazing, Capillary action, Braze welding, Brazing rod, Oxyacetylene welding, Neutral flame, Carburizing flame, Regulator, Arc welding, Polarity, Striking an arc, Weld bead, Slag, MIG, TIG, Black light, Fluorescent penetrant, Developer solution, Dye penetrant, Crack pinning, Fusion, Blowtorch, Oxidizing flame, Filler metal, Nonferrous, Puddle, Inner flame cone, Purge, Flashback, Spark lighter, Flint, Electrode holder, Ground clamp, Gaseous shield, Blowholes.

QUIZ — Chapter 8

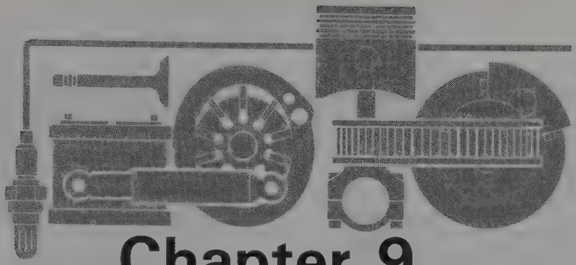
1. Soldering involves fusion. True or False?
2. Joints should be well fitted before soldering. True or False?
3. Solder is a mixture of ______________ and ______________.
4. Commonly used solder alloys are 40/60, ________, and __________.
5. Flux is used in soldering to:
   a. Clean the metal.
   b. Prevent overheating of metal.
   c. Cement parts together.
   d. Prevent rusting.
6. Three kinds of flux are: __________, __________, __________.
7. __________ flux should be used on all electrical work.
8. The tip of the iron should be well ____________.
9. When applying solder, touch the wire:
   a. To top of iron.
   b. To work away from iron.
   c. To iron where it contacts work.
   d. To side of iron.
10. Brazing involves temperatures above:
    a. 1800°F (983°C).
    b. 450°F (232°C).
    c. 800°F (427°C).
    d. 3000°F (1650°C).
11. Brazing and braze welding are one and the same. True or False?
12. Flux is required for brazing. True or False?
13. When using an oxyacetylene torch for brazing, the flame should be ______________ to slightly ______________.
14. The torch tip should be held at right angles to give better penetration when brazing. True or False?
15. For brazing, tip size and gas pressures are not too important. True or False?
16. Brazing requires that the parent metal be brought to the fusion point. True or False?
17. The flame for welding should be ____________.
18. The inner flame cone _________ _________ touch the weld puddle or rod tip.
19. Add filler metal to the weld by:
    a. Touching rod to puddle.
    b. Holding rod above puddle and allowing it to drip in.
    c. Laying a length of rod flat on the joint.
    d. Melting and depositing drops of rod all along the joint before puddling the base metal.
20. The cutting torch uses a jet of __________ to produce the cutting action.
21. Hold the cutting torch at a sharp angle to the work. True or False?
22. Acetylene tanks should be used in a __________ position.
23. The oxygen regulator has a _______ _______ thread.
24. Open tank valves ___________.
25. Always wear ___________, ___________, and ______________ when welding, brazing, or cutting.
26. Before opening tank valves, regulator handles should be:
    a. Removed.
    b. Backed out until free.
    c. Tightened securely.
    d. Backed halfway out.
27. Oil and grease should be kept away from gas welding equipment. True or False?
28. Before lighting the torch, __________ both lines.
29. The acetylene tank should be opened:

   a. All the way.
   b. Four turns.
   c. One turn.
   d. 1/16 turn.

30. Some coatings will give off poisonous fumes when heated. True or False?
31. Never use acetylene pressures in excess of ________ psi (________ kPa).
32. Arc welders can be either ________ or ________ or a combination of both.
33. Arc welding imparts less heat to the work (overall) than gas welding. True or False?
34. List five welding electrode sizes suitable for garage use.
35. Welding rods are usually coated. True or False?
36. Watching the arc without protective equipment can cause serious eye damage. True or False?
37. Rod ________ and ________ must be in keeping with the job.
38. The hotter the arc, the better. True or False?
39. Describe the sound of a proper arc.
40. Never weld, braze, or solder fuel tanks until special precautions have been taken. True or False?
41. Describe four methods of crack detection.
42. Cracks can often be repaired without heat by using the ________ technique.
43. TIG and MIG welding are used on ________ and ________ metals.
44. Gas shielding prevents weld contamination by ________ and ________ in the surrounding air.



A submerged arc welder shields the "arc" and molten metal from contaminants in the air to produce a high-quality weld. (Miller Electric)



Chapter 9

CLEANING EQUIPMENT AND TECHNIQUES

After studying this chapter, you will be able to:

☐ List the most common automotive cleaning techniques.

☐ Compare the advantages and disadvantages of different cleaning methods.

☐ Select the correct cleaning method for the job.

☐ Describe safety rules that apply to various cleaning techniques.

Cleaning parts, on the car or off, can be a slow, tedious job unless the proper equipment and methods are used. Part cleaning can account for nearly one-half the time involved on a job. To use even more time with poor equipment and techniques will increase repair charges. The shop will be hard pressed to offer competitive repair price schedules. Time is like money - it must not be wasted.

BE THOROUGH

On an in-car engine clean, or an under-body clean job, leaving a few "holidays" (missed spots) will displease the customer, but mechanically will not prove disastrous. On the other hand, careless cleaning of parts during engine, transmission, or rear end teardowns may ruin the job and cause expensive comebacks and poor customer relations.

The only safe course is to be absolutely meticulous in your cleaning. Remove ALL foreign materials from the part and protect against contamination during storage and handling.

NUMEROUS TYPES

Cleaning equipment and techniques vary with the size and type of job. You are obviously not going to fire up a steam cleaner to clean one universal joint when solvent, brush, and air hose will handle the task quickly. On the other hand, attempting to clean the outside of an engine prior to disassembly with a brush and solvent would be equally foolish. You must tailor the equipment and solution to the job at hand.

This chapter will deal with the widely used techniques. Study them carefully so you will be able to choose wisely.

CLEANING WITH WIRE BRUSH AND SCRAPER

Engine valves, combustion chambers, piston heads and grooves are subject to accumulations of hard carbon. If they are not soaked in powerful cleaners, they must be cleaned with scrapers and power brushes.

The heavy deposits can be knocked off with scraping tools and a power wire wheel. A drill-driven rotary brush may also be used for final cleaning.

Clean when dry. After thorough carbon removal, the part should be washed in solvent and blown dry. NEVER USE A POWER BRUSH ON SOFT ARTICLES SUCH AS PISTONS, CARBURETORS, OR BEARING INSERTS. Fig. 9-1 shows carbon deposits

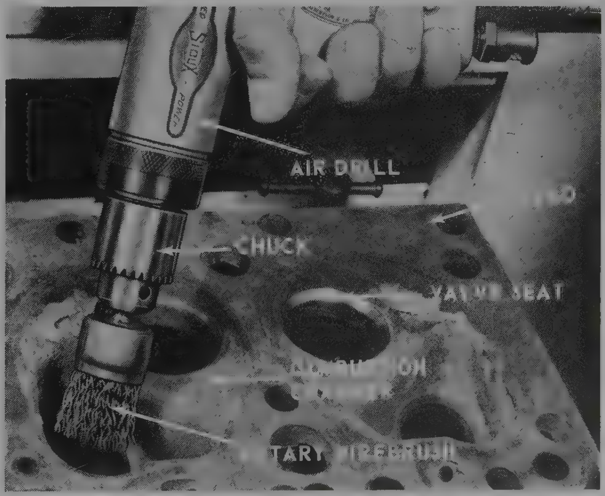


Fig. 9-1. Removing combustion chamber deposits with a rotary wire brush. (Albertson & Co.)

in a cylinder head combustion chamber being removed with a rotary wire brush chucked in an air-operated drill.

GET ADVICE

A number of companies offer various types of cleaning equipment and solutions designed to perform tasks such as car body washing, in-car engine cleaning, carburetor cleaning, block cleaning, hard carbon removal. There are hot solutions, cold solutions, high-pressure and low-pressure sprays, and agitators. So many are available that it can cause confusion to anyone not an expert in the field. When choosing a cleaning solution or piece of equipment, it is wise to consult other shops or mechanics for their reactions. Also, discuss the problem with sales representatives from reliable companies offering products in this field.

SOLUTIONS CAN BE DANGEROUS

Many cleaning solutions are TOXIC (poisonous) and CAUSTIC (will burn skin, eyes). Be certain you know WHAT you are using and follow the manufacturers' recommended handling procedures.

General safety rules concerning cleaning solutions are:

1. Use in a well-ventilated area.
2. Never use gasoline for cleaning.
3. Wear goggles or face shield when working with the powerful types.
4. Keep away from sparks and open flame.
5. Do not smoke around solutions.
6. Keep solutions covered when not in use. Keep in labeled containers.
7. Use solutions with relatively high flash points (temperature at which vapors will ignite when brought into contact with an open flame).
8. Never heat solutions unless specifically recommended.
9. Avoid dampening clothing with solvent.
10. Always READ and FOLLOW manufacturers' instructions.
11. When brushing parts in solvent, use a nylon or brass bristle brush to avoid sparks.
12. A large tank of solvent should have a lid that is held open by a fusible link (holding device that will melt and drop the lid in the event of fire).
13. Wash hands and arms thoroughly when cleaning job is complete.
14. Avoid prolonged skin exposure to all types of solvents.

PARTS WASHER

Although small parts can be cleaned in cans or buckets, a far faster and more efficient job can be done with a regular cold solution parts washer.

The better parts washers hold considerable solvent, have soaking trays, solvent agitation, and a filter to remove impurities from the solvent for rinsing. Fig. 9-2 illustrates a typical parts washer. They are available in many different sizes.

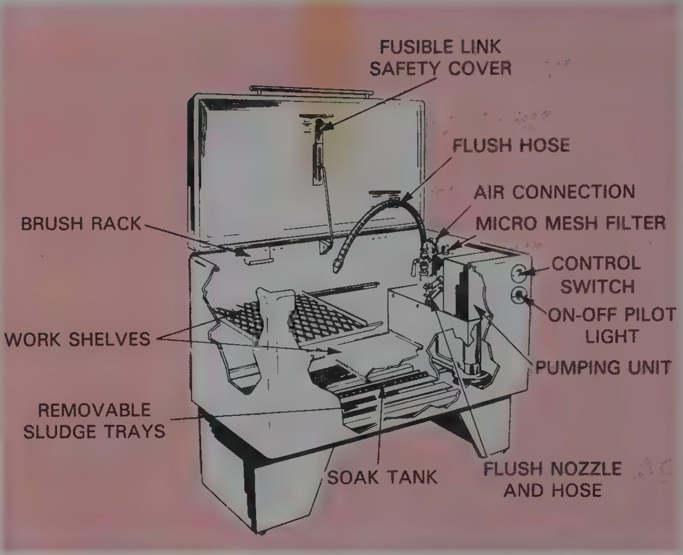


Fig. 9-2. Typical cold solution parts washer. (Graymills)

To use the parts washer, the heaviest deposits can be quickly removed with a scraper. On large units such as engines, steam clean before disassembly.

The parts are placed in the basket and submerged in the solution. Parts with hollow areas should have the hollows facing up so that an air trap will not prevent solution entry, Fig. 9-3.

The solution is then agitated (shaken) by air pressure or the solution passing through nozzles under pressure. The washer shown in Fig. 9-4 has a separate compartment that is air agitated. The main tank is used for soaking, brushing, and rinsing.

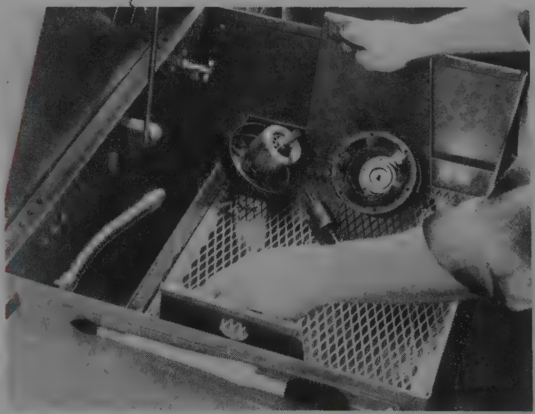


Fig. 9-3. Place parts in basket and submerge in solvent.

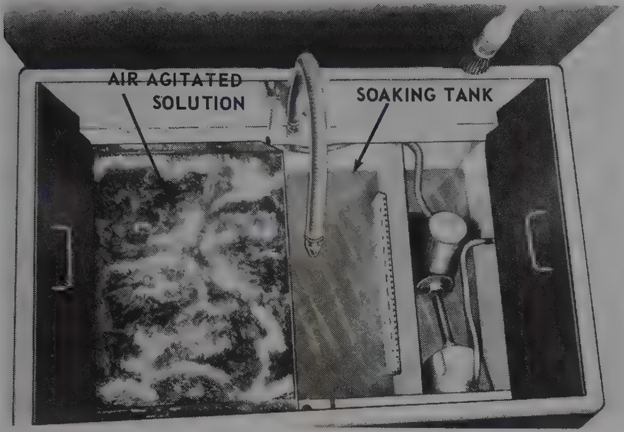


Fig. 9-4. Parts washer with both air agitated and soaking tanks. (Kleer-Flo)

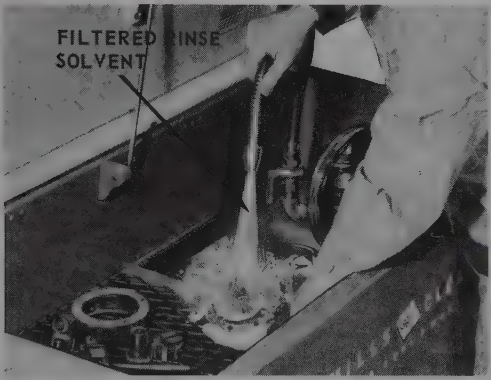


Fig. 9-5. Mechanic rinsing some parts while others wash.

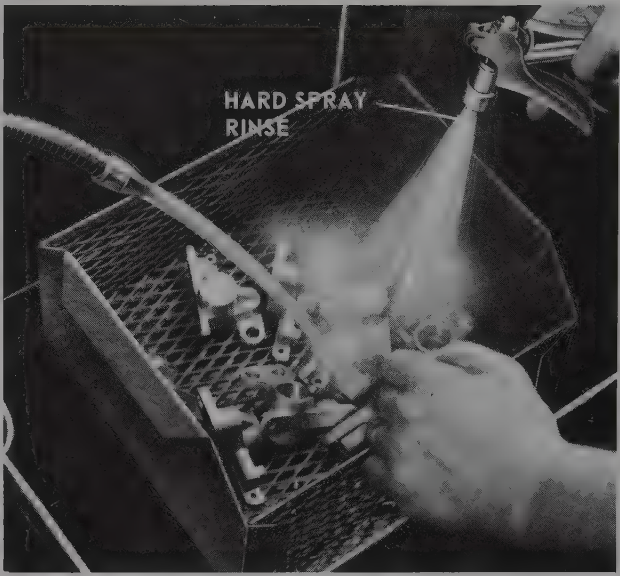


Fig. 9-6. Giving parts a final rinse in filtered solvent. Solvent must be CLEAN!

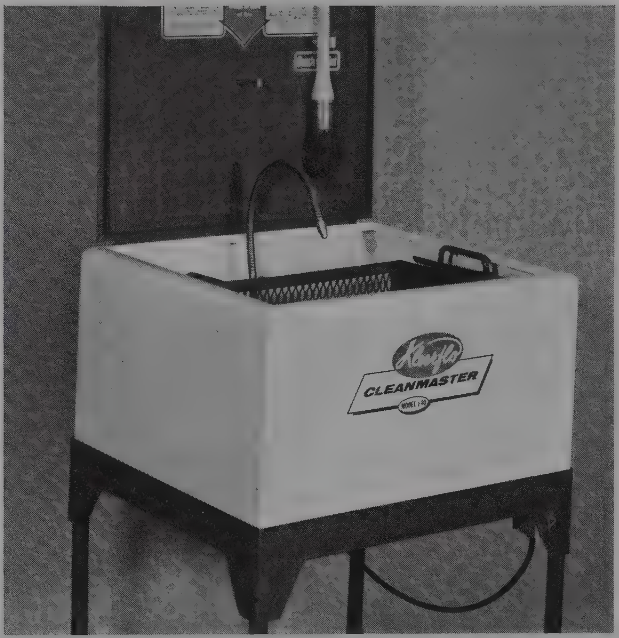


Fig. 9-7. Handy portable parts washer. (Kleer-Flo)

During the agitation cycle, some washers have a separate basket. It will hold a few of the parts for brushing or rinsing while the remainder are still washing. See Fig. 9-5.

After thorough cleaning, the parts should be given a final rinse. The machine shown in Fig. 9-6 has both a soft rinse and hard spray rinse.

Following rinsing, let parts drain and then blow dry. If there is a possibility of rust formation, oil or grease the part. Keep parts covered until ready to use.

Some garages utilize portable parts washers that may be wheeled to the job, Fig. 9-7.

"HOT TANK" CLEANING

Large garages or shops specializing in rebuilding usually have a "hot tank" for heavy cleaning. Engine blocks, some transmission cases, and radiators are quickly and thoroughly cleaned in the hot tank.

The hot tank usually uses a strong alkaline compound mixed with water to form a solution. Temperature runs between 180-210°F (82-99°C). The tank may have an agitator to speed cleaning. Most parts are clean in thirty minutes or less, depending on tank design, solution strength, temperature, and part load.

The alkaline solution is CAUSTIC. When cleaning aluminum parts, the solution must be inhibited (weakened) to prevent surface erosion.

When the parts are removed from the tank, they should be thoroughly washed, preferably with hot water. Be careful to flush out oil galleries, water jackets, and other internal passages. Parts or surfaces subject to rusting should be oiled.

BE EXTREMELY CAREFUL WHEN USING THE "HOT TANK." OBSERVE ALL SAFETY PRECAUTIONS. HAVE SOMEONE SKILLED IN ITS USE GIVE YOU INSTRUCTIONS BEFORE USING.

Fig. 9-8 shows engine blocks, heads, and other parts being lowered into two different types of hot tanks. Note cranes on tanks that aid in moving heavy parts.

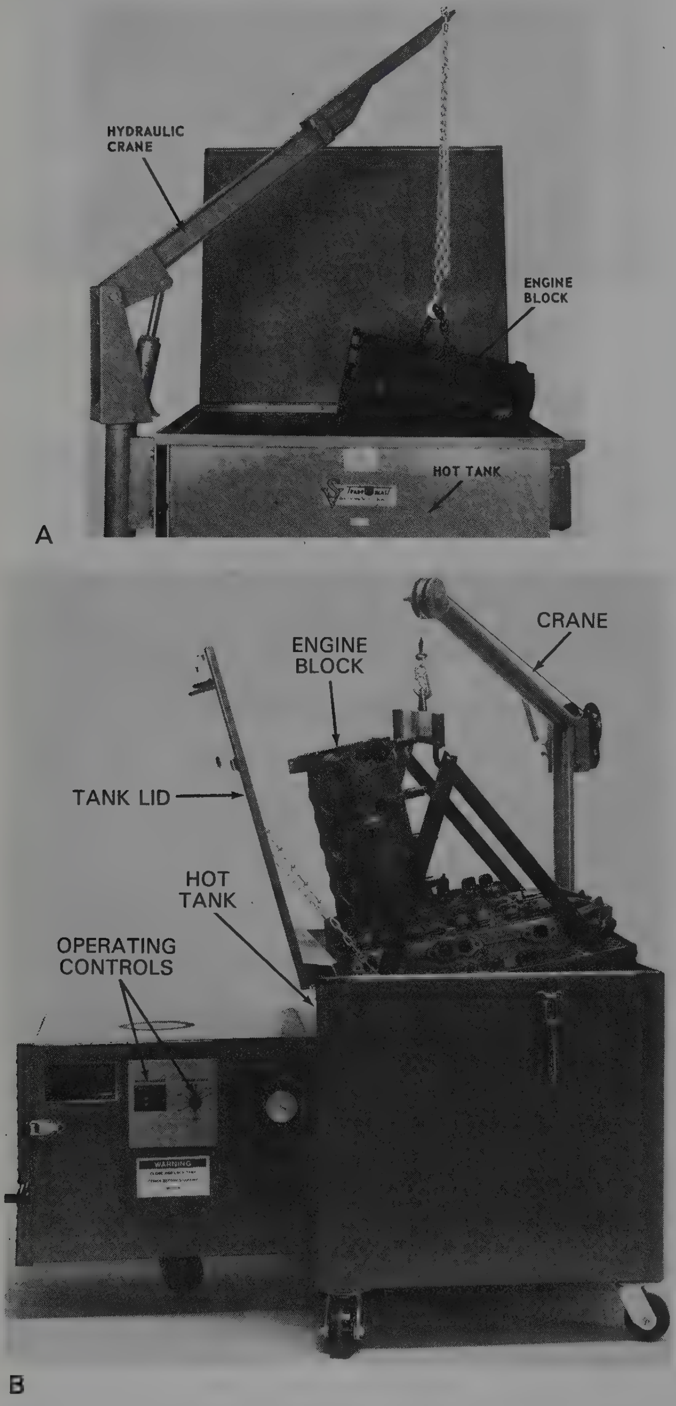


Fig. 9-8. Hot tanks. A—Engine block being lowered into a hot tank with a hydraulic crane. B—Various engine parts being placed in hot tank. This design provides a high degree of agitation to aid cleaning. (Storm-Vulcan and Hurri-Clean)

STEAM CLEANING

The steam cleaner is excellent for many types of cleaning. Under-car, engine, and transmission cleaning are all handled quickly and thoroughly.

In operation, a water pump forces water, with a metered amount of cleaning solution, through a pipe formed into a number of coils. A heat source (oil or gas) passes heat up through the coils quickly, generating steam pressure. From the coils the superheated water is passed into a flexible steam hose that is attached to a steam gun. The gun has a heatproof handle and adjustable nozzle.

Some units feed the cleaning solution into the gun instead of the water supply. Fig. 9-9 shows a typical portable steam cleaner.

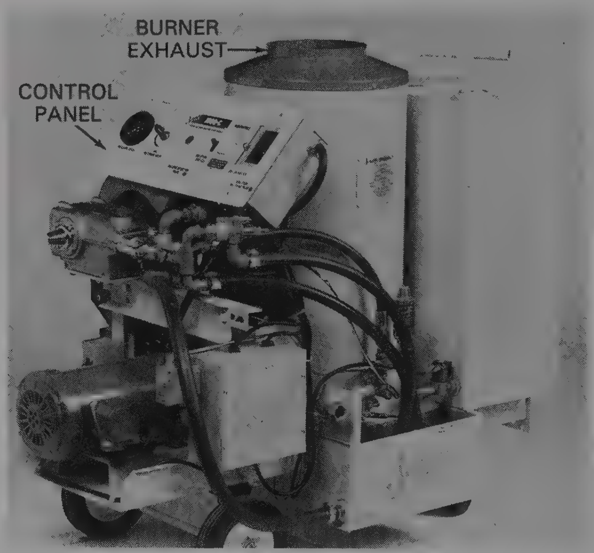


Fig. 9-9. Portable steam cleaner. Steam hose and gun are not shown. Exterior cover has been removed to show construction. (Homestead Valve)

GENERAL OPERATION RULES FOR STEAM CLEANERS

There are a number of cleaners on the market. As always, the manufacturers' instructions should be followed regarding specific steps and maintenance procedures. There are, however, a number of operational steps that are common to almost all steam cleaners. These will be discussed.

STARTING THE CLEANER

The steam cleaner, if operated inside, must have adequate ventilation. The machine should be properly grounded electrically.

Turn on the water source. The water pump should then be switched on. In a short time, you will notice a stream of water flowing from the gun. This indicates that the heating coils are filled with water and that the burner can be ignited without burning the coils.

Ignite the burner. When the gun begins to emit steam, adjust the fuel valve to bring the pressure to the desired limit.

If the machine utilizes an integral solution tank, check to see if enough solution is present. Mix the solution by opening the stirring valve for about 30 seconds. If no stirring provision is present, place the gun nozzle into the solution and agitate it with steam pressure. If the solution is desired, open the solution valve.

USING STEAM CLEANER

Cover fenders and windshield area when doing an engine or under-hood job. Remember that the cleaning solution can spot paint. When finished, flush all painted surfaces with clean water. Cover carburetor, generator or alternator, distributor, master cylinder, power steering pump, and smog pump. Avoid prolonged steaming of wiring. Keep away from air conditioning lines. Avoid close up or prolonged steaming of all electrical units.

Depending on the nozzle design, type of dirt to be removed, and shape of object being cleaned, hold the gun nozzle from one to four inches (25 to 102 mm) from the surface. If the nozzle is too far from the work, cleaning is slowed down considerably.

The steam should be "wet" (ample hot water along with steam) as dry steam will not clean or flush surfaces well.

Avoid oversteaming the tie rod, suspension knuckles, and other under-car bearing areas. Excessive steaming will melt the lubricant as well as damage the seals. Do not drive dirt and grease from the brake backing plates into the brake drum. Take it easy on brake lines and flex hose.

Remember that steam causes condensation. Do not operate in a poorly-ventilated area as part and tool rusting will occur. Fig. 9-10 shows an operator steam cleaning the underside of a car.

SHUTTING DOWN STEAM CLEANER

When finished with the cleaner, first shut off the solution control valve. Allow the cleaner to operate a short time. Then, shut off the fuel valve. Keep the water pump running until there is no sign of steam vapor coming from the gun. The pump may then be shut down. By following this procedure, all solution is removed from the coils. The coils will be cooled down before the water flow has stopped, thus preventing possible burning and scaling.

Arrange the steam hose so that it is out of the way and will not be kinked or run over. If the surrounding temperature will drop below freezing, the machine should be drained. Fig. 9-11 illustrates how an automatic transmission is steam cleaned prior to disassembly.

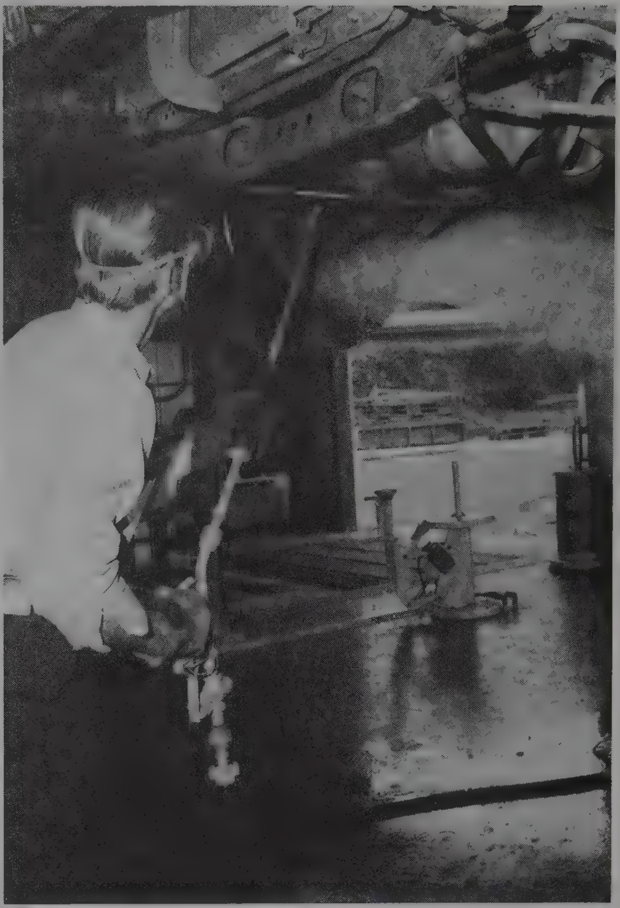


Fig. 9-10. Using steam cleaner on under-body cleaning. Note use of goggles. (Clayton Manufacturing Co.)

SAFETY RULES FOR STEAM CLEANING

1. Do not operate without proper burner ventilation.
2. Steamer must have a good electrical ground.
3. Keep pressure within specified limits.
4. Wear a face shield to keep splatters from entering your eyes.
5. Keep other personnel away from the immediate vicinity. When swinging the gun around, be careful of any unexpected bystanders.
6. If the machine does not ignite readily, shut off the fuel valve and have a qualified repairperson check the burner fuel and ignition system.
7. Read the machine instruction book carefully and get "checked out" by an experienced operator.
8. If the machine must be lighted by hand, keep face and body away from burner opening.

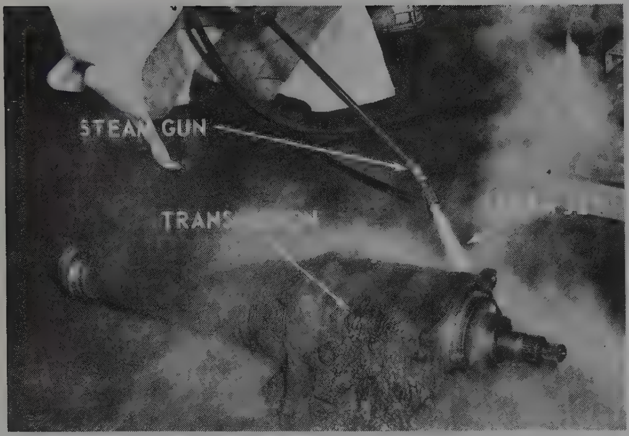


Fig. 9-11. Steam cleaning an automatic transmission prior to disassembly.

HIGH-PRESSURE SPRAY CLEANING

Effective cleaning can be accomplished through the use of cold, high pressure tap water into which a cleaning solution is injected. Pressure at the nozzle runs up to around 500 psi (3 448 kPa).

By adjusting the gun, a soft mist, containing a detergent solution, is sprayed over the object to be cleaned until thoroughly saturated. Following a short waiting period to allow the deposits to soften, a fine, hard, fan-shaped stream of plain water is used to lift off the dirt. For hard to clean corners, the spray can be adjusted to a high velocity, narrow stream.

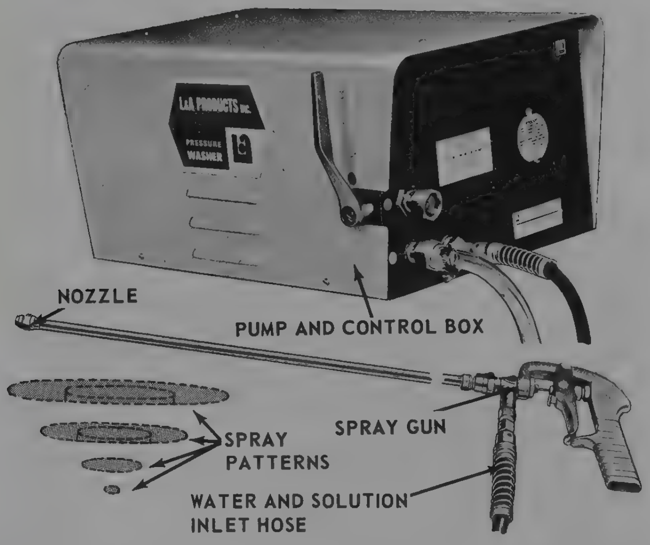


Fig. 9-12. High-pressure spray cleaner. (L & A Products)

As with steam cleaning, when doing an under-hood cleaning job, cover fenders and windshield areas. Fig. 9-12 illustrates a high-pressure cleaning machine. Note the different spray patterns available.

LOW-PRESSURE SPRAY CLEANING

This is another technique involving the use of an air-operated mixing gun. As air passes through the gun, it draws in a metered amount of cleaning solution and sprays it on the object being cleaned. After waiting for deposits to soften, the object can be washed down with a hose. Also, the cleaning gun suction hose can be dropped in a container of water or cleaning solvent, depending on the need.

Special cleaning solutions are generally added to water, kerosene, or cleaning solvent for the initial cleaning spray. NEVER USE GASOLINE OR ANY LOW FLASH POINT SOLVENT. SPRAYING ATOMIZES THE SOLVENT, THUS RENDERING IT HIGHLY EXPLOSIVE. See Fig. 9-13.

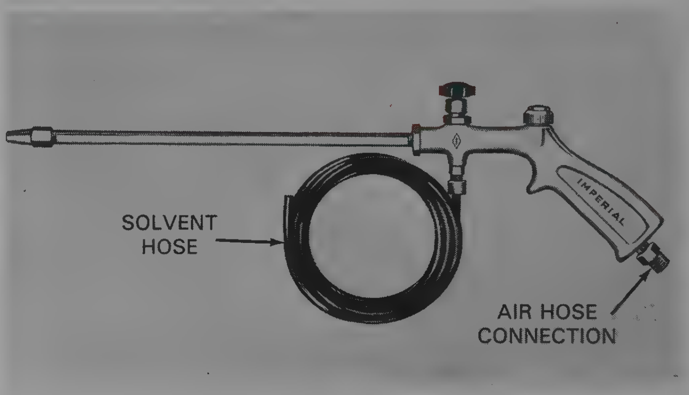


Fig. 9-13. Low-pressure spray gun. Hose is placed in container of solvent. (Imperial Brass)

REMOVE BATTERY GROUND CABLE

Whenever doing under-hood cleaning, it is a good idea to remove the battery ground cable. This prevents possible short circuits that could be caused by grounding a hot wire or terminal with the cleaning gun.

COLD SOAK-CLEANING

For soak-cleaning, the part or parts are placed in a basket and lowered into the cleaning solution. Following a period of from ten to thirty minutes, the parts are removed and rinsed in solvent or water. They are then blown dry with an air gun.

Solutions of various kinds for specific applications such as carburetor, piston, etc., cleaning are available. Most of the solutions are extremely caustic. KEEP AWAY FROM SKIN AND EYES!

The solutions generally come in a special pail or drum that includes a parts basket. The solution is far enough from the top so that a normal load of parts will not displace enough to cause spillage. A special sealing solution floats on top to prevent evaporation and excessive odor. When placing parts in the container, make certain they are completely submerged and are below the special seal solution. Fig. 9-14 depicts a typical six gallon (22.8 Litres) pail of soak-cleaning solution. Notice the parts basket.

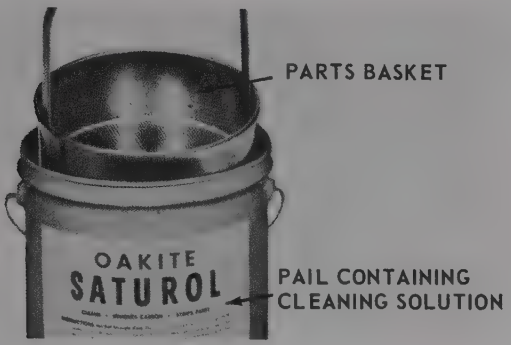


Fig. 9-14. Soak-cleaning kit. This particular solution is especially designed for gum, varnish, and hard carbon removal. (Oakite)

VAPOR CLEANING

The cleaner illustrated in Fig. 9-15 cleans parts by heating a Perchlorethylene solution. The resultant vapors remove deposits on the parts suspended in the metal basket. The solution is nonflammable.

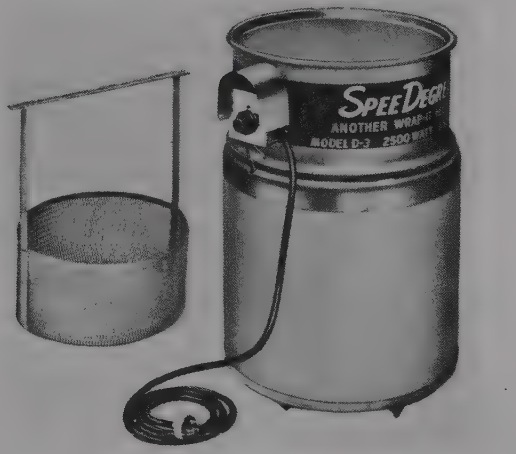


Fig. 9-15. Vapor cleaning unit. Use only recommended solvent. (ACRA Electric)

SANDBLAST CLEANING

With the exception of spark plugs, automotive parts are rarely sandblasted. The body shop and welding shop has occasional use for a sandblaster, for quickly removing paint, rust, and welding scale.

A special blast gun, operating under air pressure of around 50 to 200 psi (345 to 1 379 kPa), draws in a metered amount of abrasive material (aluminum oxide, silica sand, metal shot) and propels it against the object with great force.

Always wear a face shield. In situations that are prolonged or produce much dust, wear a breathing mask also.

Never sandblast around a repair area. The abrasive will contaminate parts—with disastrous results. Fig. 9-16 shows sandblasting a weld.

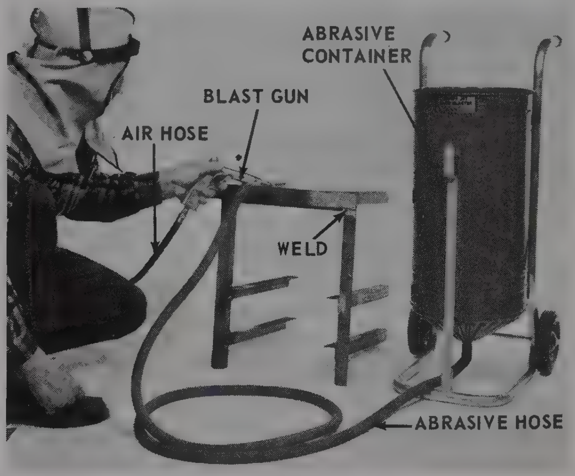


Fig. 9-16. Sandblasting a weld to remove slag. (A.L.C. Co.)

SUMMARY

Automotive repair and maintenance work require considerable use of cleaning techniques, equipment, and solutions.

You will do faster and better work if you select the best cleaning procedure for the job at hand. As with all work, cleaning must be THOROUGH.

Hand brushes and scrapers are occasionally useful. Power brushes are fine for removal of hard carbon from some parts.

Remember that many cleaning solutions are both toxic and caustic and must be handled with care.

A cold solution parts washer is excellent for many parts not coated with hard carbon. Parts are soaked in an agitated solution, brushed, rinsed, and blown dry.

For larger objects or parts that are hard to clean, a hot tank, containing a strong alkaline solution, is desirable. Aluminum parts will not stand full strength hot tank solutions.

The steam cleaner is a fast and efficient cleaning tool and is especially good for removing heavy dirt and grease deposits. Under-hood and under-body cleaning is easily accomplished.

High-pressure spray cleaning handles dirt and grease very well. Large areas may be cleaned quickly.

Low-pressure spray cleaning is effective on many jobs. It is generally somewhat slower than either steaming or using the high-pressure washer.

Cold soak-cleaning solutions are widely used for gum, varnish, and hard carbon removal. Pistons, carburetors, and automatic transmissions are usually cleaned in such a cleaner. A parts basket can be furnished with the pail or drum of solution.

Vapor cleaning has some advantages and works particularly well on certain parts.

Sandblast cleaning is useful for paint, rust, and weld scale. Do not operate a sandblaster near a repair area.

Cleaning solutions can be dangerous. Observe all safety rules.

SUGGESTED ACTIVITIES

Get instructions in the use of the various pieces of cleaning equipment in your shop. Use them. If you are a student, visit as many garages as possible. Observe the cleaning techniques used. Always ask the shop foreman or service manager first for permission to visit. Do not get in the way. Do not touch equipment and avoid unnecessary conversation. Upon leaving, thank the mechanics concerned as well as the manager.

LOOK "SHARP"

Obviously mechanics get dirty. There is no need, however, to stay dirty. At the end of each working day, a thorough cleansing of the hands with one of the many industrial hand cleaners will clean and condition your hands.

Have your uniforms (coat, coveralls, pants) cleaned regularly. A neat haircut and fresh uniform will keep you looking "sharp."

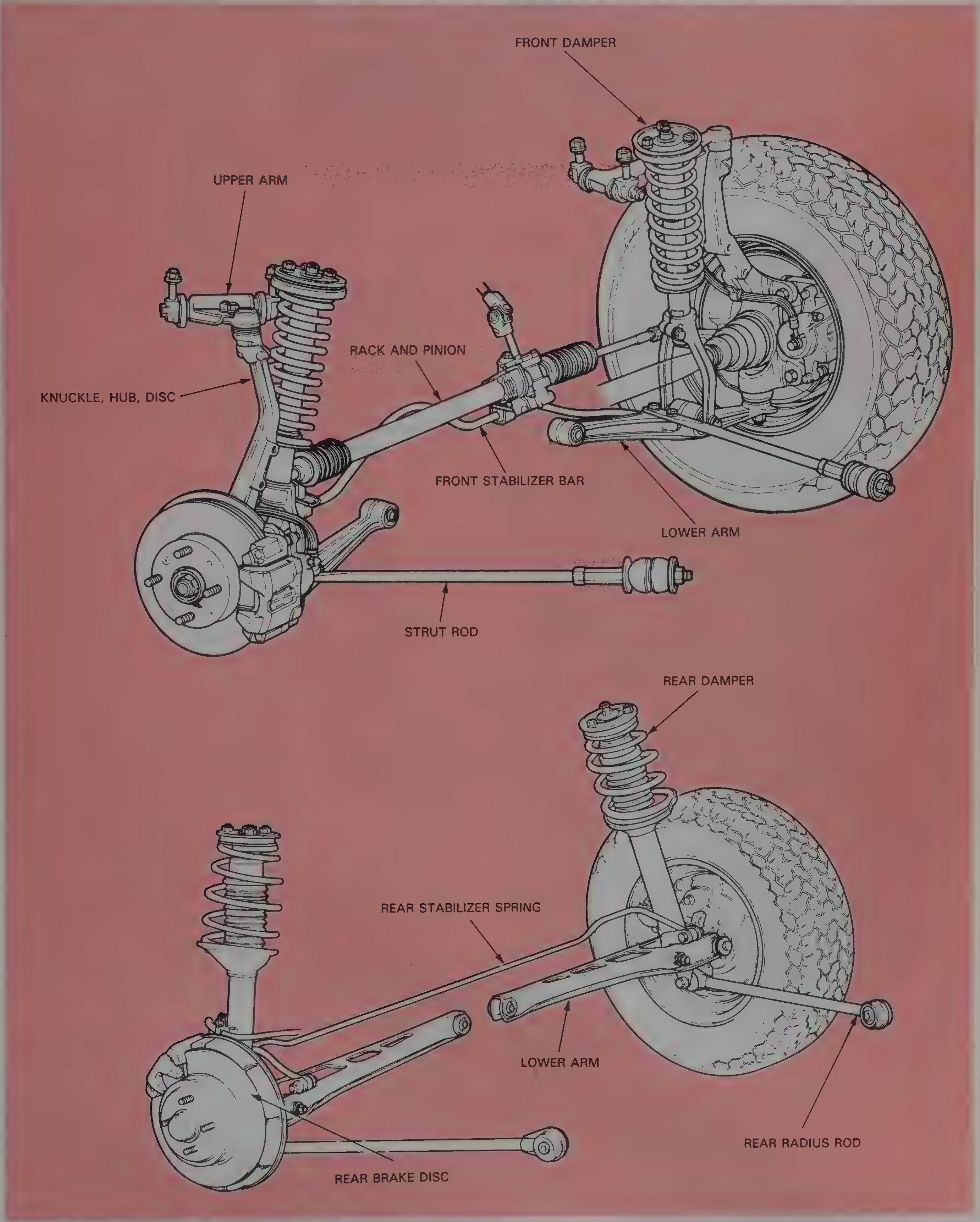
A garage must be concerned about its public "image." The building, equipment, floors, and personnel must all present a favorable appearance. Do your part!

KNOW THESE TERMS

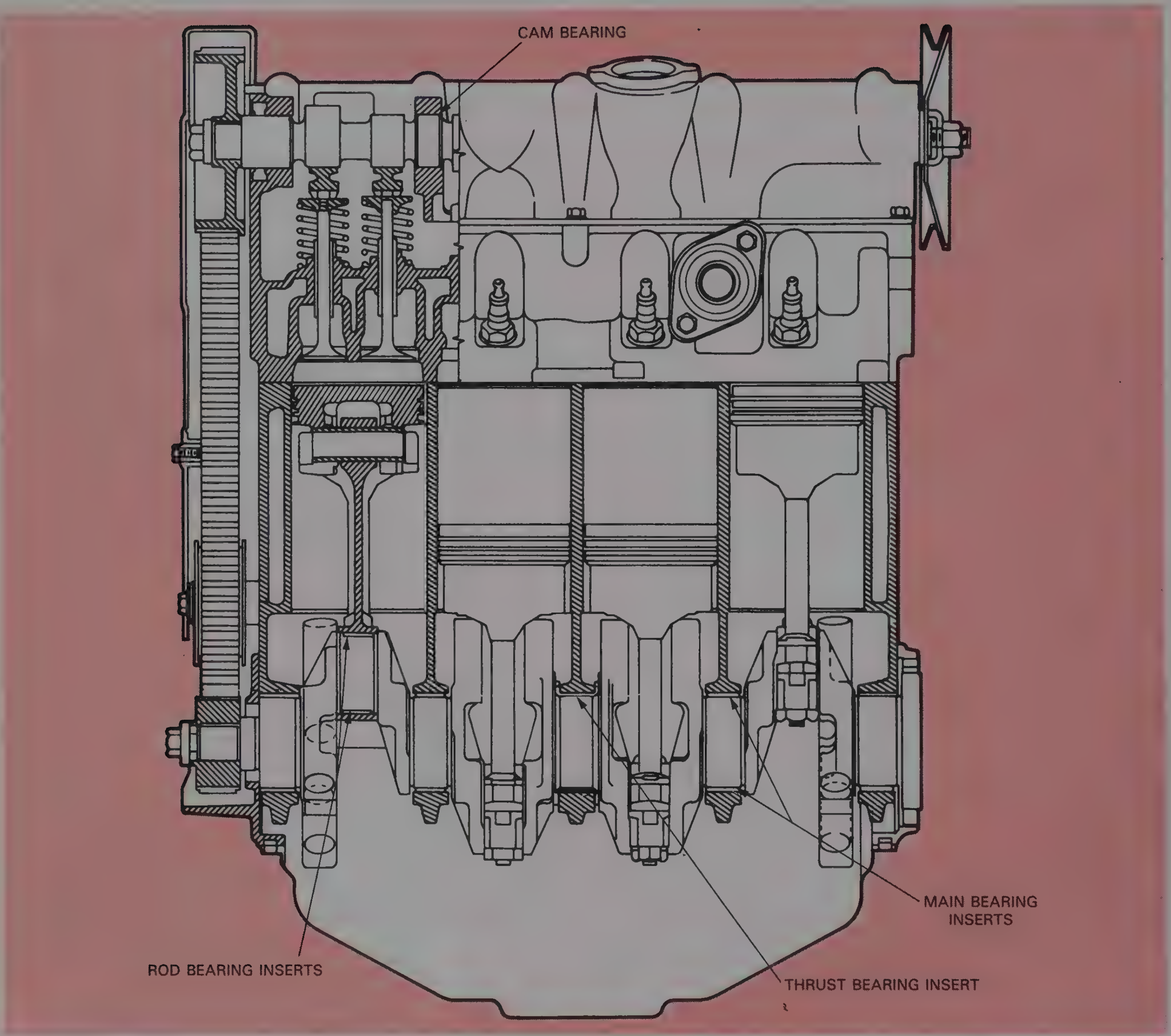
Rotary wire wheel, Toxic, Caustic, Parts washer, High flash point, Soaking tray, Agitation, Hot tank, Steam cleaning, High-pressure spray cleaning, Low-pressure spray cleaning, Cold soak-cleaning, Vapor cleaning, Sandblasting, Face shield, Air drill, Sludge tray, Alkaline compound, Inhibited cleaning solution, Steam gun, Nonflammable, Silica sand, Metal shot.

QUIZ - Chapter 9

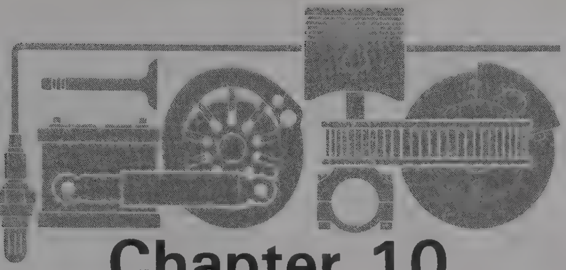
1. Cleaning often accounts for 1/10, 1/5, or 1/2 of the total repair time.
2. A shop with a steam cleaner really does not need any other type of cleaning equipment. True or False?
3. Piston ring grooves are best cleaned with the power wire wheel. True or False?
4. List ten safety precautions that should be observed when using cleaning solutions.
5. Cleaning means: 1. Getting most of the deposits removed. 2. Getting every single bit of foreign material removed. Circle correct answer.
6. A cold solution parts washer is effective for hard carbon removal. True or False?
7. When submerging a part with an airtight compartment or hollow, always place the hollow ____________ so that the solution will enter.
8. The "hot tank" is excellent for cleaning engine blocks. True or False?
9. The solution used for hot tank cleaning is both toxic and caustic. True or False?
10. Steam cleaning should be done in a closed area. True or False?
11. Always start the water pump before lighting the burner on a steam cleaner. True or False?
12. To stop the steam cleaner, shut off the water pump and when no water comes from the gun, shut off the burner. True or False?
13. Keep the steam nozzle about one to four inches (25 to 102 mm) from the work. True or False?
14. Cover the ____________ and the ____________ areas before steaming under the hood.
15. List six safety rules to observe when using the steam cleaner.
16. High-pressure spray cleaning will do a good job of removing dirt and grease. True or False?
17. Gasoline, or any flammable, low flash point solvent, if used for cleaning, can cause a serious fire or explosion. True or False?
18. It is a good idea to remove the ______________ ______________ ______________ when cleaning under the hood, to prevent accidental short circuits.
19. Carburetors are best cleaned in a strong alkaline solution such as that used in some cold soak-cleaning pails. True or False?
20. Machined engine parts may be cleaned satisfactorily with the sandblaster. True or False?


FRONT DAMPER
UPPER ARM
RACK AND PINION
KNUCKLE, HUB, DISC
FRONT STABILIZER BAR
LOWER ARM
STRUT ROD
REAR DAMPER
REAR STABILIZER SPRING
LOWER ARM
REAR RADIUS ROD
REAR BRAKE DISC

Front and rear suspension systems. Note use of rack and pinion steering and four wheel disc brakes. (Honda)


CAM BEARING
MAIN BEARING INSERTS
ROD BEARING INSERTS
THRUST BEARING INSERT

An engine uses numerous friction bearings. It is extremely important that you understand their operation, construction, and service. (Chrysler)



Chapter 10

FRICTION BEARINGS

After studying this chapter, you will be able to:
- ☐ Compare the differences between friction and antifriction bearings.
- ☐ Explain the application of different bearing designs.
- ☐ Properly install friction bearings.
- ☐ Diagnose common reasons for bearing failures.

Bearings can be classified as FRICTION or ANTIFRICTION. The friction bearing contact area SLIDES against the bearing journal surface (that portion of shaft designed to accept bearing). The antifriction bearing utilizes ball or roller elements that ROLL against the contact area. This reduces, but does not eliminate, friction.

Both types are used in the automobile. Major use of the friction bearing is confined to the engine, Fig. 10-1. The antifriction bearing is used in such areas as the transmission, transfer case, drive line, and differential. See Fig. 10-2.

ENGINE FRICTION BEARINGS

The camshaft, crankshaft, and connecting rods all use friction type bearings. Antifriction bearing application in these areas is largely confined to small, high speed engines used for boats and chain saws.

CAST OR SPUN BABBITTED BEARINGS

For many years, most automobile engines used the cast babbitted bearing. The babbitt (tin, antimony, copper) metal was melted and poured into the bearing area. It was then carefully bored to a specified size. Shims (thin strips of steel or brass) were often placed between the two halves. As the bearing became worn, the shims could be removed, thus reducing the clearance.

As engine horsepower and rpm increased, the cast babbitted rod failed to provide proper strength and wear characteristics. Rebabbitting was expensive. Adjustment by the use of shims was time consuming. Unless adjustment was done carefully, it often produced poor fits. Today, babbitt bearings have been largely replaced by PRECISION INSERT bearings.

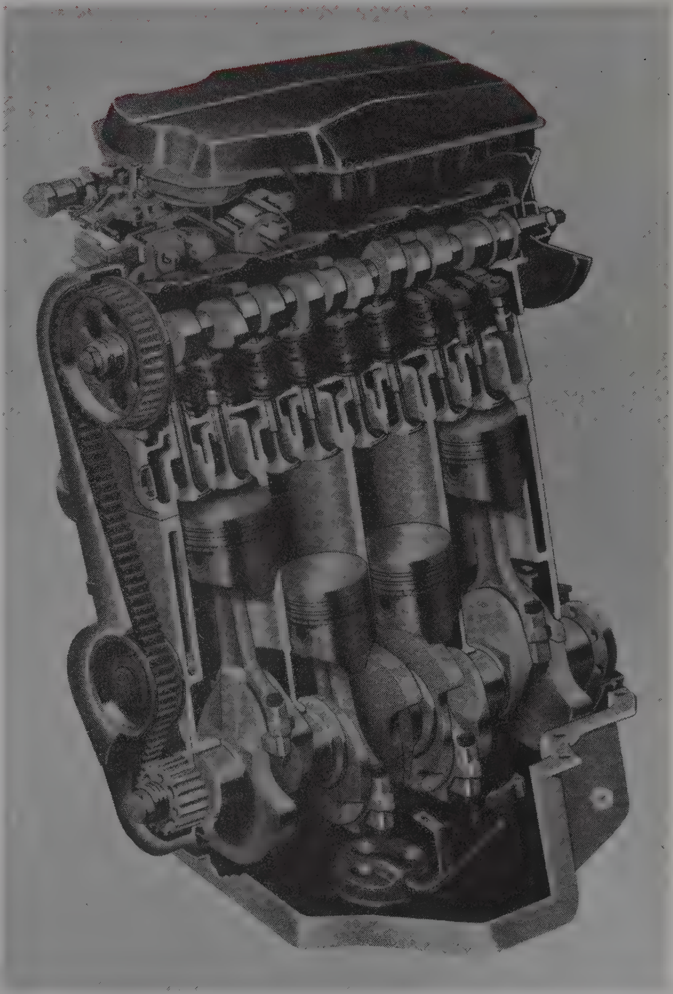


Fig. 10-1. Automobile engine makes use of a great many friction bearings. How many are you able to find and identify? (Chrysler)

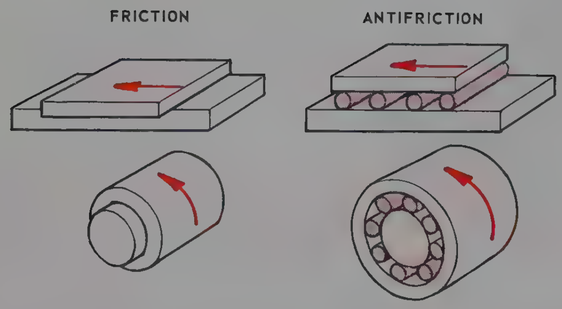


Fig. 10-2. Friction bearing uses a sliding contact while antifriction bearing utilizes a rolling contact.

PRECISION INSERT BEARINGS

The precision insert bearing is light and strong. It possesses excellent bearing characteristics. It is available in a wide range of sizes, and is quickly replaced. It does, however, demand care in handling and installation. Precision insert bearings are made in both one and two-piece types.

Most insert bearings utilize a steel (low carbon) back. One or more layers of other materials (lead-tin babbitt, copper alloy, and aluminum alloy) are bonded to the back.

A lead-copper alloy can be affixed to the steel back by a process known as sintering. The lead and copper are melted together. Through a process of atomization, this mixture is reduced to very tiny (.002-.005 in. or 0.05-0.13 mm) particles. This powder is then spread on the steel. By heating and rolling under pressure, it is compressed into a relatively solid layer that adheres to the steel. Look at Fig. 10-3.

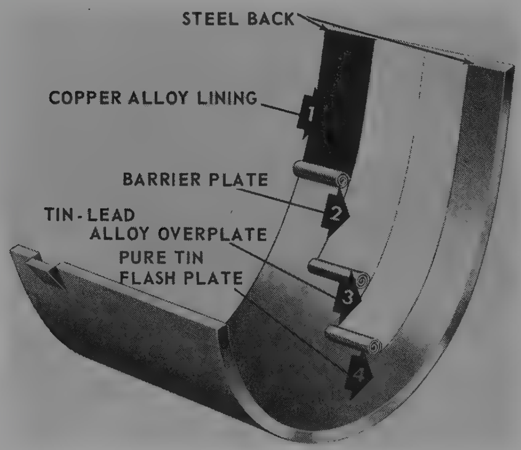


Fig. 10-3. Five layer (counting steel back) insert bearing.

In Fig. 10-3, the steel back is covered with copper alloy lining. A barrier plate, about .000075 in. (0.001905 mm) thick, is plated over the copper alloy. The barrier plate prevents tin in overplate from entering copper alloy. A thin overplate (about .001 in. or 0.025 mm) of tin-lead alloy is applied to the barrier plate. An extremely thin, final coating of pure tin is flash plated over entire bearing. The flash tin prevents rusting and oxidization of steel back and parting surfaces (edges where bearing halves come together).

Other bearing lining combinations are shown in Fig. 10-4.

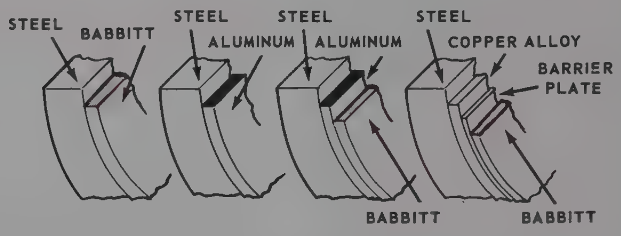


Fig. 10-4. Some insert bearing lining combinations.

THRUST FLANGE

Whenever an insert bearing must control thrust forces (pressure parallel to shaft centerline), a thrust flange is incorporated on one or both sides of the bearing. The thrust faces are lined with bearing material such as used on the bearing proper. Some thrust flanges are not part of the bearings, but are inserted as separate pieces, Figs. 10-5 and 10-34.

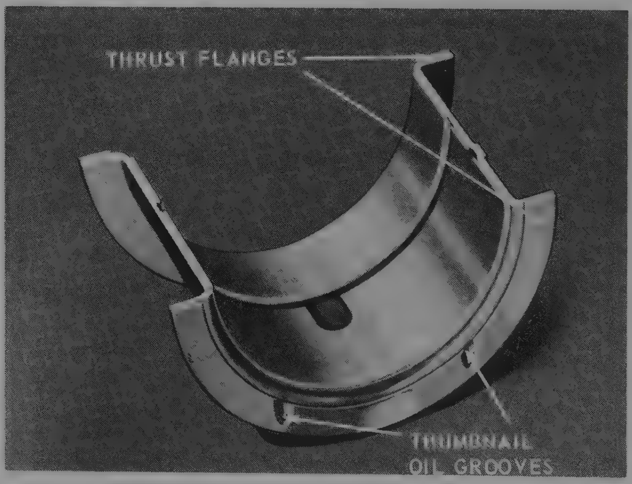


Fig. 10-5. Crankshaft main bearing with thrust flanges. (Clevite Service)

INSERT MUST FIT HOUSING PROPERLY

To provide adequate support, heat transfer, and alignment, it is essential that the insert contact the housing or cap properly. Inserts are manufactured to produce proper fit by using bearing spread and crush.

BEARING SPREAD

The insert diameter across the parting edges is slightly larger (.005-.030 in. or 0.13-0.76 mm) than the bore. This makes it necessary to force or snap the insert into the bore by applying thumb pressure to the parting edges. DO NOT FORCE THE INSERT INTO PLACE BY PRESSING ON THE CENTER. THIS COULD WARP THE INSERT.

Spread also helps hold the bearing in place during assembly operations, Fig. 10-6

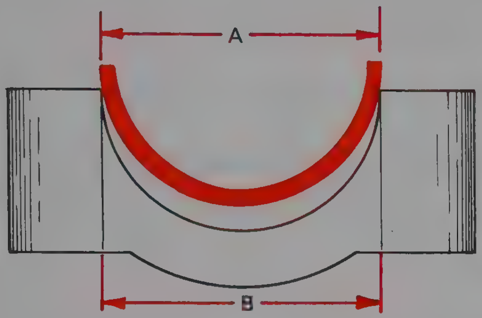


Fig. 10-6. Positive bearing spread. Note that diameter A across parting surface is slightly larger than bore diameter B.

BEARING CRUSH

The insert is also designed so that after it is snapped into place, the parting edges will protrude a slight amount above the bore parting edge. In effect, each insert half is slightly larger than a full half circle. Refer to Fig. 10-7.

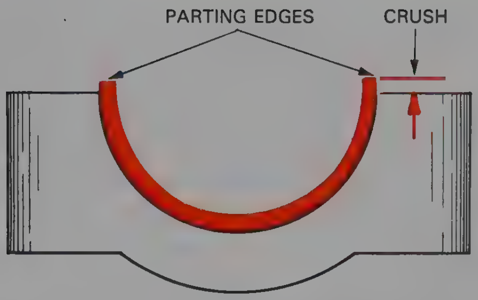


Fig. 10-7. Bearing CRUSH. Note that both insert parting edges (exaggerated for emphasis) protrude slightly above cap.

When the bearing is bolted together, the crush area touches first. As tightening progresses, the crush area is forced beneath the bore parting edges. This creates a tight insert-to-bore contact through radial pressure. Look at Fig. 10-8.

NEVER FILE BEARING CAPS OR CRUSH. TO DO SO MAY RUIN THE BEARING.

INSERT MUST NOT TURN

With the exception of the floating insert mentioned, inserts are provided with locating lugs or dowels to prevent the insert from turning. WHEN INSTALLING INSERTS, BE CERTAIN THE LUGS ARE PROPERLY ALIGNED WITH THE SLOTS IN THE HOUSING. DOWELS MUST ENTER THEIR HOLES. See Fig. 10-9.

INSERT AND HOUSING BORE MUST BE SMOOTH AND CLEAN

The housing bore, insert back, and parting surfaces must be free of all nicks, burrs, or foreign materials.

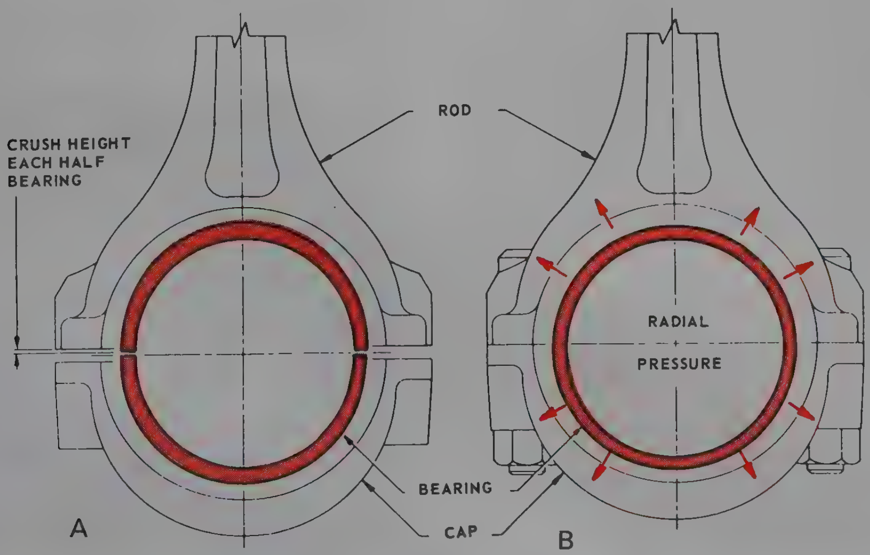


Fig. 10-8. When rod and cap are drawn together as in B, bearing crush, as shown in A, produces radial pressure, forcing insert tightly against bore.

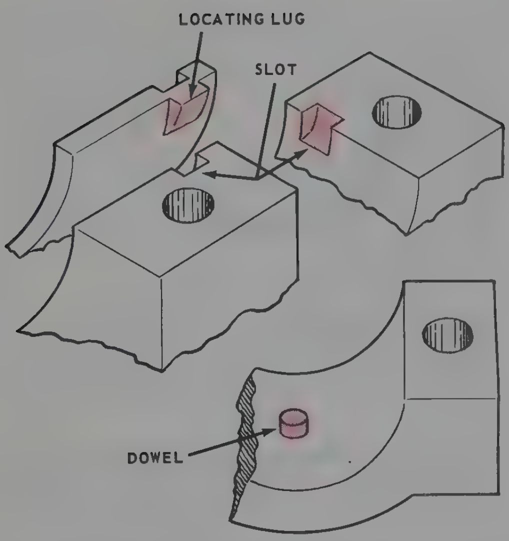


Fig. 10-9. Locating lugs and dowels keep the insert from turning.

If the insert is prevented from making perfect contact, pressure spots, misalignment, and overheating will result. ALWAYS CAREFULLY CHECK THE HOUSING BORE AND INSERT BACK TO MAKE CERTAIN THEY ARE SMOOTH AND CLEAN. DO NOT OIL THESE SURFACES.

HOUSING BORE HALVES MUST BE ALIGNED

Even though the bore and insert are clean and the insert spread and crush are correct, the bearing will still be ruined if the upper and lower (in case of split bearings) bore halves are not properly aligned. It is possible to reverse some bearing caps (lower halves). This will shift the upper and lower bores out of alignment. WHEN DISASSEMBLING BEARING CAPS, ALWAYS MARK THE UPPER AND LOWER HALVES BEFORE REMOVAL. PREFERABLY, USE NUMBERS SO THAT YOU MAY REPLACE THE CAP IN ITS ORIGINAL POSITION. See Fig. 10-10.

The inserts should always be saved for study. If they appear usable, mark them on the back with a fine scribe. If plans include replacement, you may mark them on the bearing surface.

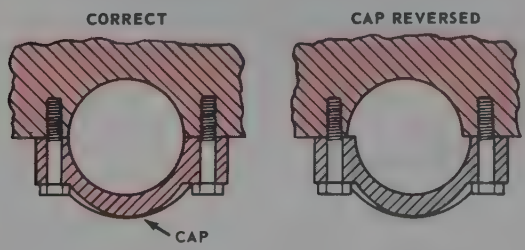


Fig. 10-10. Reversing bearing caps will shift upper and lower bore halves out of alignment.

WRENCH SIDE PRESSURE CAN ALSO DESTROY CAP ALIGNMENT

Thick wrenches can create enough pressure against the cap to shift it out of alignment. Use the correct size socket. Tighten by alternating from one bolt or nut to the other. WHEN CAP IS JUST SNUG, TAP LIGHTLY WITH A PLASTIC HAMMER TO ASSIST CAP ALIGNMENT. USING A TORQUE WRENCH, TORQUE THE FASTENERS TO THE RECOMMENDED VALUE. Study Fig. 10-11.

HOUSING BORES MUST BE ROUND

The heavy stresses within the engine can cause the housing bores to elongate. When the insert is installed

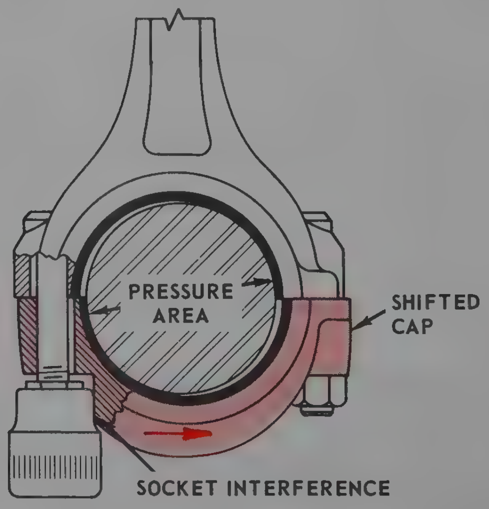


Fig. 10-11. Thick wall socket has exerted side pressure, thus shifting cap to one side.

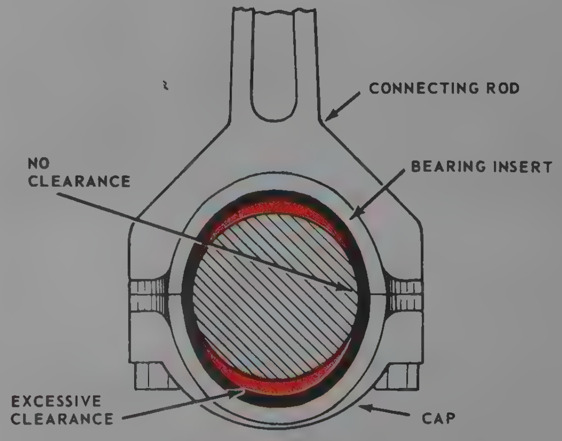


Fig. 10-12. Elongated rod bearing bore. Note excessive clearance at top and bottom while zero clearance exists at sides. Insert life would be short.

in such a bore, it will conform to the bore elongation, thus providing an egg-shaped bearing surface. Clearance in one direction will be excessive while clearance in the other will be nonexistent, causing extreme friction and wear. Such bores must be reconditioned, Fig. 10-12.

ALL BORES MUST BE ALIGNED

The block, through the effects of heating and cooling, can become distorted. This will throw the camshaft and crankshaft bearing bores out of alignment. This, in turn, will force the camshaft and crankshaft out of alignment, creating heavy bearing loading and uneven stressing. See Fig. 10-13.

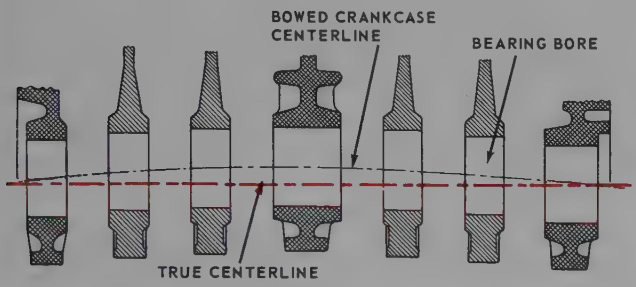


Fig. 10-13. A bowed crankcase will shift main bearing bores out of alignment with their true centerline.

DO NOT MIX BEARING HALVES

Insert halves come in pairs. It is important that they are not mixed.

OIL GROOVES AND HOLES

The insert is often drilled to permit oil to enter freely. In other cases, holes are used to allow oil passage to other areas. Annular, thumbnail, and distribution or spreader grooves are often incorporated. Not all inserts are drilled or grooved, Fig. 10-14.

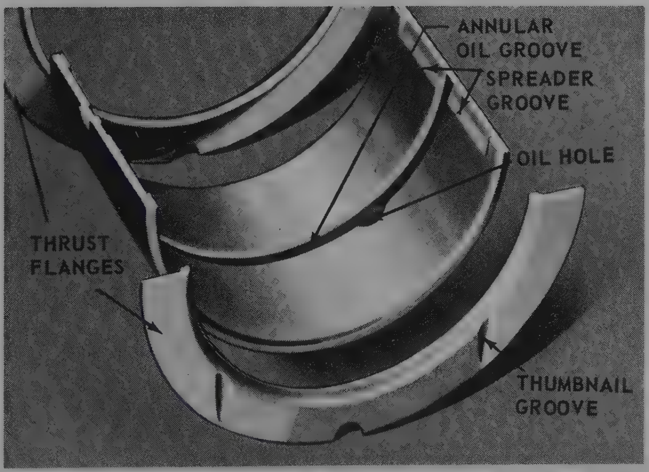


Fig. 10-14. Typical insert bearing oil grooves. This particular main bearing uses separate thrust flanges. (Clevite Service)

If one of the insert halves is drilled and the other is not, be certain to place the drilled half in the drilled bore. Neglecting to do this can cause immediate bearing failure. When installing full round inserts, such as the camshaft bearings, make sure the oil holes are aligned. Look at Fig. 10-15.

Fortunately, many split bearings are manufactured with both halves drilled to prevent improper assembly.

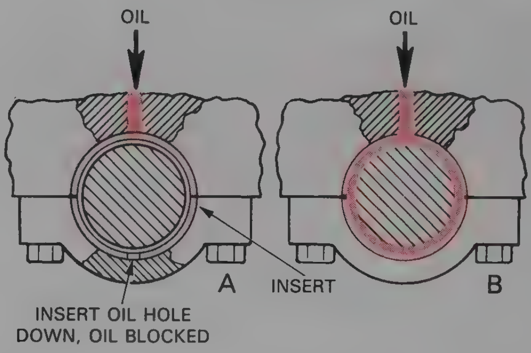


Fig. 10-15. Align insert oil with oil passage. A—Insert oil hole has been placed down, cutting off oil supply. B—Insert oil hole aligned with passageway. Proper lubrication will result.

BEARING OIL CLEARANCE

The precision insert bearing must have enough clearance to allow oil to penetrate and form a lubricating film. The clearance must provide proper flow through the bearing to aid in cooling and passage to other critical areas needing lubrication.

On the other hand, too much clearance will allow so much oil flow that it can lower oil pressure. It can also cause excessive "throw off" (oil running from bearings and being thrown off crankshaft at high velocity). This, in turn, will flood the cylinder walls with oil beyond the capacity of the piston rings to control. Excessive clearance will also allow movement between parts sufficient enough to literally pound the bearing

RECOMMENDED OIL CLEARANCES FOR ENGINE BEARINGS

SHAFT-SIZE	**SB** (High lead or tin base)	**CA** (Copper Alloy)	**AP & CP** (Over plated bearing)	**AT** (Aluminum Alloy)
$2 - 2\frac{3}{4}$	.0010	.0020	.0010	.0025
$2\frac{13}{16} - 3\frac{1}{2}$	.0015	.0025	.0015	.0030
$3\frac{9}{16} - 4\frac{1}{2}$	.0020	.0030	.0020	.0037

NOTE: Chart above indicates mininum diametral clearances. For maximum permissible clearance, add .001"

Fig. 10-16. Typical average minimum clearances for engine bearings. (Federal-Mogul)

to pieces.

WHEN INSTALLING INSERT BEARINGS, ALWAYS FOLLOW THE ENGINE MANUFACTURERS' RECOMMENDED BEARING CLEARANCES.

The chart in Fig. 10-16 shows AVERAGE MINIMUM CLEARANCES for engine bearings of different sizes and types. The chart is intended to indicate average clearances only, and should not be used when engine manufacturers' recommendations are available.

CHECKING BEARING CLEARANCE

Approximate clearance of engine bearings can be determined by attaching an engine "prelubricator" (air pressure operated oil tank). Observe the amount of oil dripping from the bearings. This is often done after the pan is removed, but before disconnecting any bearings. It gives the mechanic an approximate idea of bearing condition. The prelubricator is used again after engine assembly to charge the lubrication system with oil. At the same time, it provides a final visual check on bearing clearances.

One of the most common methods of obtaining precise clearance measurements is a special plastic wire (trade name Plastigage). A section is placed either on the journal or on the insert. The bearing is tightened, then removed. The plastic will be flattened. By using a paper gauge supplied with the wire, the width of the wire can be accurately related to clearance in thousandths of an inch, Fig. 10-17.

Complete instruction on the use of the prelubricator and Plastigage will be given in the chapter on engine overhaul.

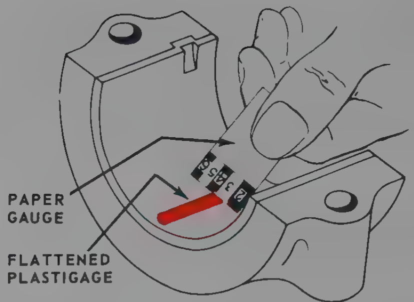


Fig. 10-17. Checking bearing clearance with Plastigage. Bearing has .003 in. (0.08 mm) clearance.

UNDERSIZE BEARINGS

To compensate for wear, inserts are available in a series of undersizes. If journal wear is slight, the recommended clearance can often be obtained through the use of inserts .001 or .002 in. (0.025 or 0.05 mm) undersize. The shaft must be carefully measured and the largest diameter compared to the original size to determine the correct undersize.

When journal wear is severe or when journals are scored or egg shaped, inserts are available in .010, .020, .030 (0.25, 0.51, 0.76 mm) undersize. The shaft is ground to one of these undersizes. This brings the bearing condition and clearance up to acceptable standards.

Occasionally semifinished (greatly undersize) inserts are bored out to a specified size.

PRECISION FULL ROUND CAMSHAFT BEARINGS

The camshaft bearing is constructed like the connecting rod and crankshaft inserts. However, they are a

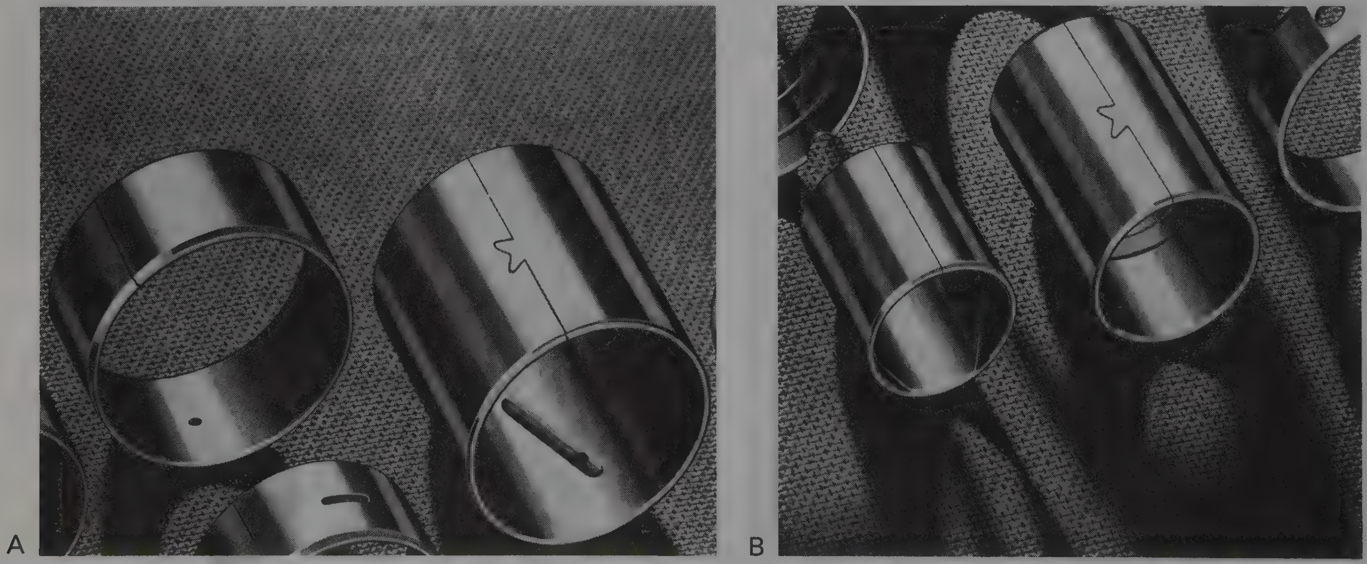


Fig. 10-18. A—Typical camshaft insert bearings. B—Typical bushings. These are steel backed precision type. (Clevite Service)

one piece design.

The camshaft bearing must be pressed into place. In addition to the standard sizes, they are available in large undersizes to permit line boring. Line boring is done by attaching a cutter to a long, rigid steel bar. The bar is passing through the bearings one after the other, thus boring them in line with each other.

The bearing material is affixed to steel strip stock. The stock is rolled into a full circle with either a butt or butt and clinch joint. The bearing material is usually babbitt, Fig. 10-18, A.

BUSHINGS

Bushings are full round bearings, usually made of solid bearing bronze (mixture of copper, lead, tin, zinc). They can also be made by the sintering process. Some applications use steel back precision bushings. In general practice though, the bushing is pressed into place and either bored, reamed, or honed to size. Bushings are usually of smaller diameter than bearings and are used for slower speed applications, Fig. 10-18, B.

BEARING JOURNALS

The section of a shaft that contacts the bearing surface is termed a JOURNAL. It must be ROUND, SMOOTH, AND STRAIGHT. Nicks and scratches will ruin the bearing material, Fig. 10-19.

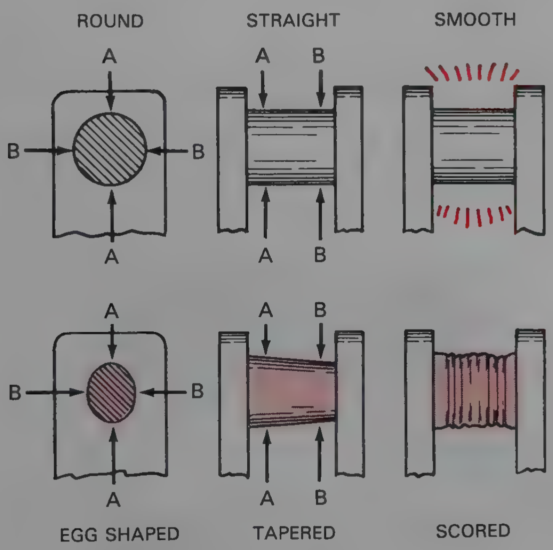


Fig. 10-19. Bearing journals must be round, straight, and smooth.

It is recommended that a surface finish of 16 micro inches or smoother be attained. The micro inch (one-millionth 0.000001 of an inch) is used as a measurement of surface finish. To measure a surface finish in micro inches, tests are made to determine the depths of all grooves or scratches. The RMS (root-mean-square) or AA (arithmetical average) is used to find the AVERAGE depth. For practical purposes, this amounts to about one-third of the maximum depth. In Fig. 10-20, you will note that the red line indicates one-third the maximum depth. If the maximum depth is 90 micro inches, the measuring device would indicate a finish of 30 micro inches.

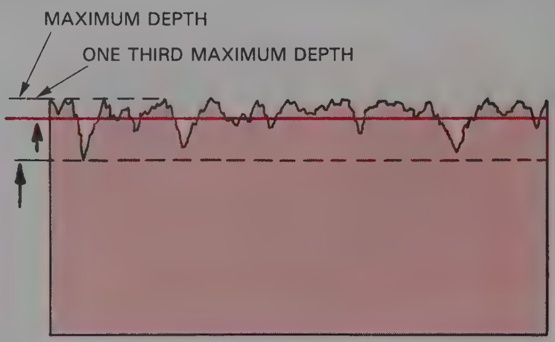


Fig. 10-20. Determining surface finish in MICRO INCHES.

HANDLING BEARINGS

Precision insert bearings are just what the name implies - they are PRECISION units and should be handled with utmost care. Do not mix halves. Protect them from dirt and physical damage. Keep fingers off of bearing surface. Finger marks can cause fine surface corrosion.

When installing, never force or pound into place. Make certain bore and insert is spotless. Locating lugs (sometimes called tangs) should be in place. After installing, coat bearing surface with CLEAN engine oil. Never file an insert. Always check for proper clearance.

BEARING FAILURE

A properly selected and installed bearing, under normal operating conditions, will last in excess of 50,000 miles (80 000 km).

There are, however, many things or combination of things, that will cause premature failure. It is important that the mechanic understand the most significant ones and be familiar with the visual effects these have on the bearing insert. In this way, by close study of the damaged bearing, the cause will often be apparent. In any case, whenever an engine is torn down, bearings should always be cleaned and carefully inspected.

DANGER SIGNALS

Bearing failure is generally preceded by a lowering of oil pressure due to increased clearance. The engine oil consumption will rise from excessive oil throw off. Finally, as the clearance increases, the bearings will start to knock.

DIRT, THE NUMBER ONE CAUSE OF BEARING FAILURE

Field and laboratory studies, over a period of many years, have proven that DIRT is the most frequent cause of bearing failure. See Fig. 10-21.

CAUSES OF BEARING FAILURE	
Dirt	42.90%
Insufficient Lubrication	15.30%
Misassembly	13.40%
Misalignment	9.80%
Overloading	8.70%
Corrosion	4.50%
Indeterminate and Other Causes	5.40%

Fig. 10-21. Causes of bearing failure and the percentage of occurrence.

DIRT

The word dirt, as used to describe foreign particle damage to moving parts, includes sand, cast iron and steel chips, pieces of bronze, grinding stone grit, and other material. NORMAL engine wear will produce fine particles worn from the various parts. Normally these are removed via the oil filtration system. They DO contribute to engine wear, but at present, will not be emphasized.

ABNORMAL engine wear will produce LARGE bits of dirt that will greatly accelerate the wear process.

DIRT FROM RECONDITIONING

Valve grinding, cylinder boring and honing, and shaft grinding deposit metal and corundum (abrasive particles). These MUST be removed by thorough cleaning. (See chapter on cleaning processes.) There is always the possibility of machined particles being present in new engines also.

DIRT FROM CLEANING

A sloppy job of cleaning often loosens carbon and other deposits but fails to completely remove them. Once the engine is assembled and put into operation, the washing and cleaning action of the oil will cause these deposits to reach the bearings. REMEMBER: DO NOT EXPECT OIL FILTERS, EVEN THE FULL-FLOW TYPE, TO COMPLETELY PROTECT THE BEARINGS. THEY CAN CLOG, THUS FORCING THE BYPASS OPEN. THIS CHANNELS LARGE CHUNKS OF DIRT DIRECTLY INTO THE BEARINGS. Final rinsing in dirty solvents often contaminates parts.

DIRT FROM POOR WORK AND STORAGE CONDITIONS

The engine may be contaminated by working under dusty conditions or by careless handling of parts. Keep clean parts covered until ready for installation. Work in a CLEAN area, protected from wind-borne dust. When not working on a part, even for a few minutes, throw a cover over it. Keep hands and tools (especially sockets) free of dirt when assembling parts. Avoid the use of the air gun, sandblaster, or steam cleaner near open engines or other units.

DIRT FROM EXTERNAL SOURCES

Once the engine is assembled and placed in service, dirt can still enter. Some of the most common sources are through the air cleaner, breather system, fuel system, cooling system, dip stick, and lubrication system. The vacuum lines can also be offenders.

Cover carburetors when the cleaner is removed. Keep air cleaners clean and properly serviced. Clean and properly service crankcase breather systems. Maintain a good filter in the fuel system. Check for coolant leaks into the cylinders (ethylene glycol antifreeze forms a gummy residue in bearings and rings and will cause serious problems). Never lay a dip stick on a dirty surface. Wipe both stick and area around stick entry hole before returning. When changing oil filters, wipe contact area thoroughly. Oil filler cans and spouts should be cleaned and stored to prevent contamination. When removing drain plugs, clean them thoroughly before replacing. Keep bulk oil tanks clean. Wipe the surface

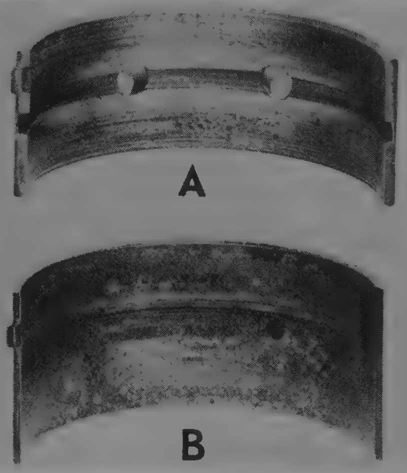


Fig. 10-22. Dirt ruins bearings - FAST! A—Dirt embedded in a plated bearing. B—Dirt impregnated babbitt bearing.

of oil cans before puncturing. Check filler tube for dirt before adding oil.

Why such a fuss about dirt? Once again: DIRT IS THE MECHANICS WORST ENEMY. GET IT OUT OF THE UNIT AND USE EVERY PRECAUTION TO KEEP IT OUT. Study the bearings shown in Fig. 10-22. Each was damaged by dirt.

BEARING LUBRICATION FAILURE

Low oil pressure caused by worn bearings, faulty pump, clogged pickup screen, or an insufficient supply of oil will cause rapid failure.

Dry starts (engine overhauled and started without charging the oil system with oil under pressure) can cause initial damage that will cut down the life expectancy of the bearings.

Loss of oil through damage to the pan, broken pump or line, leaking gasket, or failure to replace plug after draining, will cause sudden failure, Fig. 10-23.

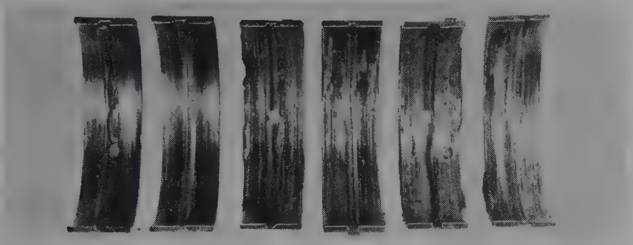


Fig. 10-23. Aluminum bearings ruined from lack of lubrication. (Federal-Mogul)

BEARING FAILURE FROM IMPROPER ASSEMBLY

As mentioned, dirt on the insert back, insufficient clearance, reversing caps, placing a lower insert in the upper position, bowed crankcase, and sprung shaft or rods will cause bearing failure. Figs. 10-24 through 10-30 illustrate the results.

OPERATIONAL FAULTS

Lugging (pulling hard at low engine rpm), excessive spark advance (firing too soon), detonation or spark knock (rapid burning of fuel charge caused by a secondary flame front), preignition (fuel charge firing before plug fires), prolonged slow idling, and excessive rpm will all place the bearings under a heavy load. This can easily lead to premature failure. When bearing condition indicates such problems, a couple of friendly tips (make certain they are friendly) to the owner would be in order, Figs. 10-31 through 10-34.

ADDITIONAL INFORMATION

Checking bearing clearance, determining bearing size requirements, prestart lubrication, bearing installation,

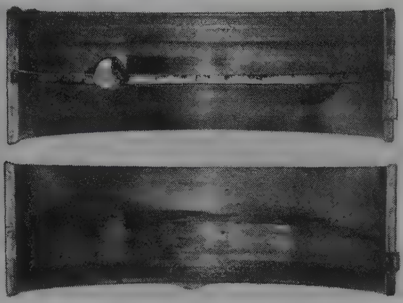


Fig. 10-24. Bearing damage from tapered housing bore.

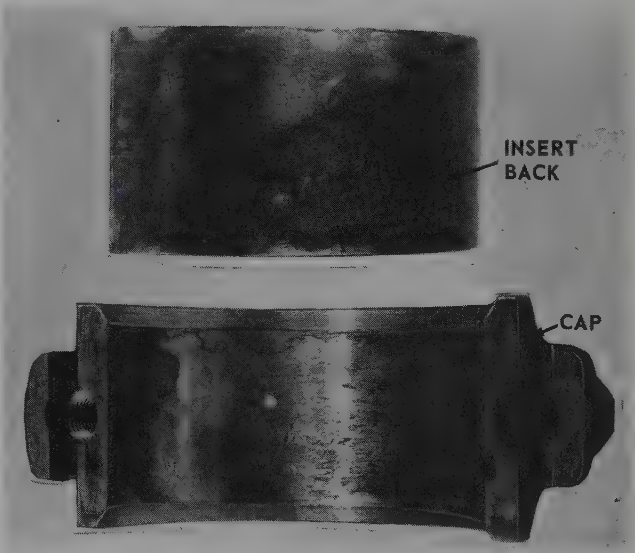


Fig. 10-25. Nicked and dented cap bore will transfer marks to back of insert, thus causing localized high pressure areas.

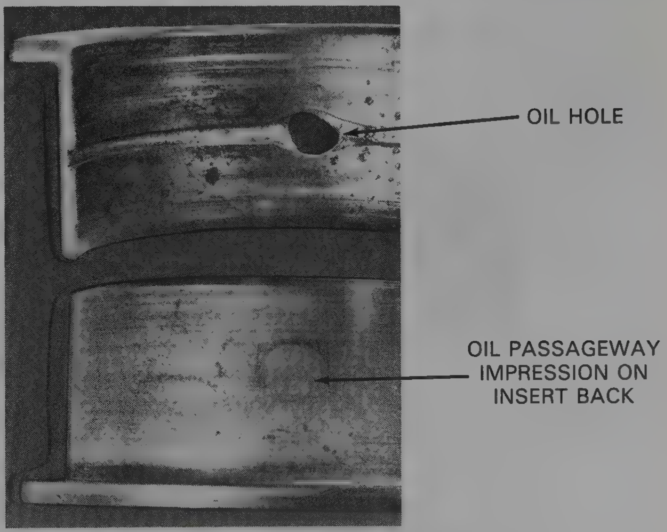


Fig. 10-26. Upper insert, with oil hole, was installed in bottom position. Lower insert (see oil passageway impression on back) blocked flow of oil to bearing.

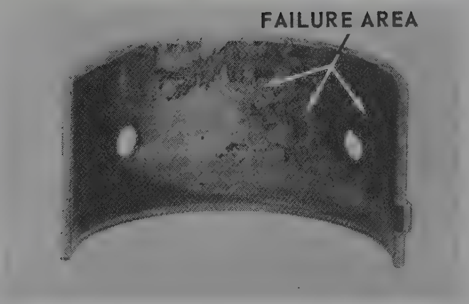


Fig. 10-27. A misaligned connecting rod placed one side of this insert under pressure. Note failure area.

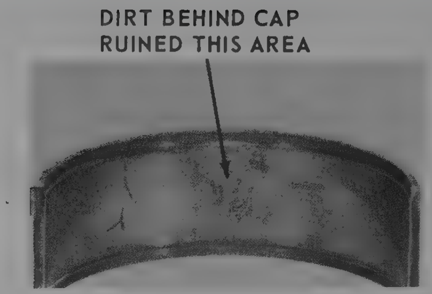


Fig. 10-30. A particle of dirt between insert and bore caused a high pressure area that damaged this bearing.

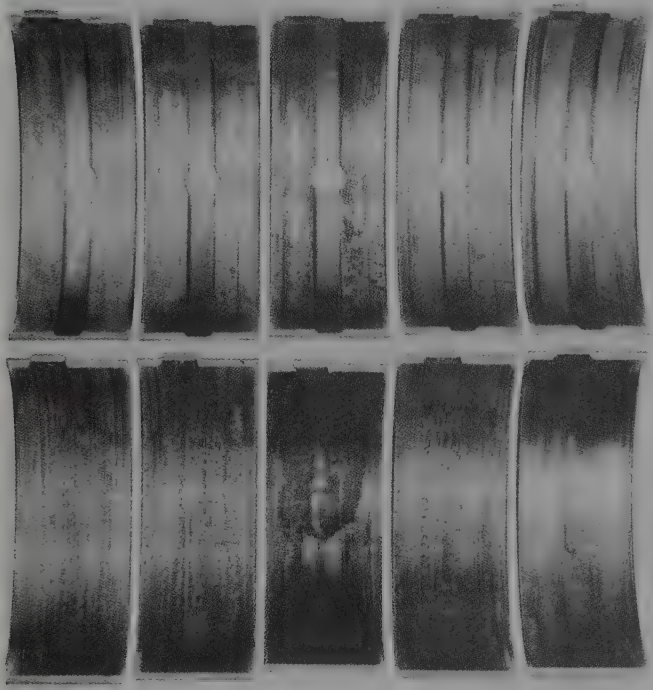


Fig. 10-28. A bowed crankcase ruined this set of main bearings.

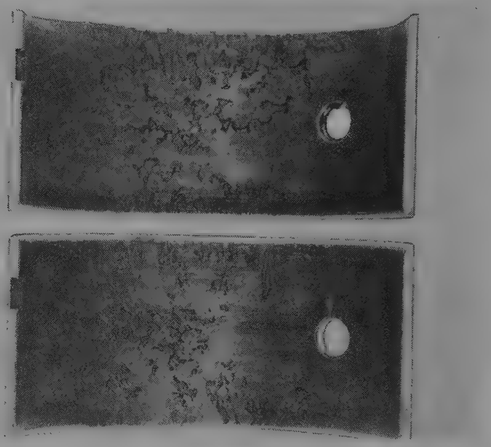


Fig. 10-31. Excessive idling will produce bearings like this.

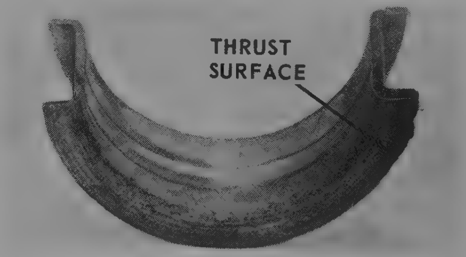


Fig. 10-32. Riding clutch (holding foot on the clutch all the time) places main bearing thrust flange under prolonged loading. Note ruined thrust surface. (Clevite Service)

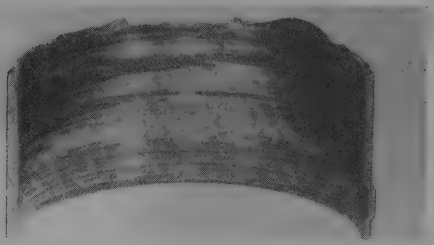


Fig. 10-29. A rough and scored journal caused this bearing to fail.

and torquing will be discussed in detail in the chapter on engine overhaul. Steel and rubber suspension system bushings will be covered in the chapters to which they pertain.

SUMMARY

The friction bearing operates with sliding friction. Friction is reduced to acceptable limits by a film of oil.

Most modern bearings are of the precision insert type. They can be of the full round or split-halves type. They utilize steel backs that can be faced with lead-tin babbitt, copper alloys, or aluminum alloy. The bearing material is often affixed by sintering. Some bearings have several layers of different materials. End thrust is controlled by incorporating thrust flanges on one or more bearings.

The insert must have intimate (close) contact with

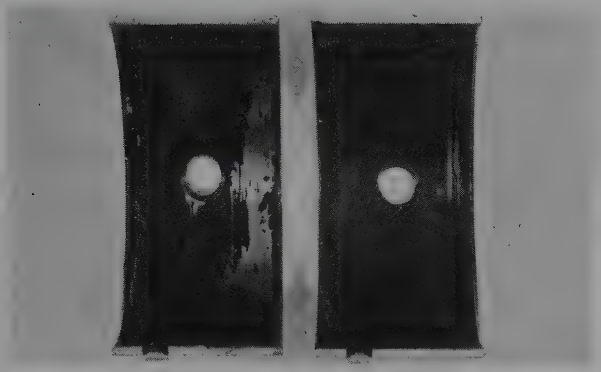


Fig. 10-33. Antifreeze leaking into pan will contaminate bearings. Note gummy deposits on these inserts. Deposits can build up and eliminate oil clearance - with disastrous results. (Federal-Mogul)

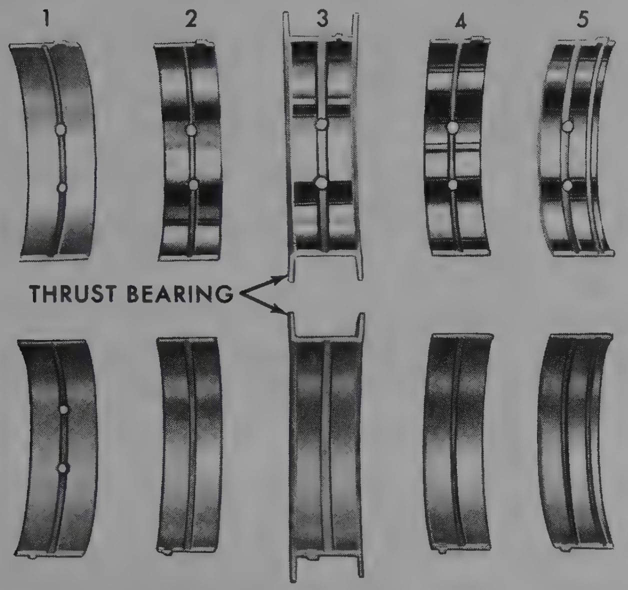


Fig. 10-34. A set of engine main bearings. Note thrust flanges on both sides of center main.

the housing bore. Bearing spread, crush, and cleanliness assure a proper fit.

Never file bearing inserts or caps.

Locating lugs should be in the proper slots. Bearing back and bore must be clean and free of nicks or foreign material.

Never reverse or mix bearing caps. Tighten properly using a torque wrench. Check bores for alignment.

Oil grooves and holes are vital. They must be located properly when installing inserts. Bearing clearance is critical. An average clearance would be around .002 in. (0.05 mm). Always follow manufacturer's recommendations.

Worn or reground journals must be fitted with undersize bearings. Common undersizes are: .001, .002, .003, .010, .020, .030, and .040 in. (0.025, 0.05, 0.08, 0.25, 0.51, 0.76, and 1.01 mm). Semifinished inserts may be bored to a specified size.

Bearing clearance is best checked with plastic wire (Plastigage).

Camshaft bearings are of the full-round type, usually babbitt lined.

Bushings are usually bronze or bronze-faced steel, and are bored, reamed, or honed to size.

Journals must be round, straight, and smooth. The micro inch is a unit of measurement used in describing surface finish. A micro inch finish of 16 or better is required for journals.

Handle bearings carefully.

Bearing failures are usually caused by dirt. Low oil pressure, excessive oil consumption, and knocking are danger signals that indicate excessive bearing wear.

Dirt enters the engine from normal wear, reconditioning, cleaning, poor work and storage conditions, through the fuel, cooling, lubrication, vacuum, and ventilation systems.

Inadequate lubrication, improper assembly, and improper driving habits also cause bearing failures.

SUGGESTED ACTIVITIES

1. Check the clearance in a bearing, using Plastigage.
2. Examine a number of bearing failures and see if you can determine the cause or combination of causes.
3. Mike a used crankshaft, both main and rod journals. Using manufacturer's specifications, determine the amount of wear. Would the shaft accept a standard undersize? Check the journals for nicks and scoring.
4. Make a collection of bushings, full-round and split. Study their construction and see if you can determine the type of bearing material.

WHO'S LAUGHING?

Your favorite suit has just been returned from the cleaners in time for "the" dance. Upon removing the garment cover, you discover a big grease stain on the lapel. Are you happy?

Or, you have an important engagement. On the way, to look your best, you stop for a quick haircut. The barber drips hair oil down the front of your shirt. Are you happy?

You are probably about as "happy" as the customer who picks up his or her car at the garage and discovers grease on the seat, smudges on the steering wheel, and chipped paint on the fenders. The customer may be slow in leaving (will probably have several thousand well chosen words to deliver to the service manager). You can rest assured the customer will be a lot longer coming back.

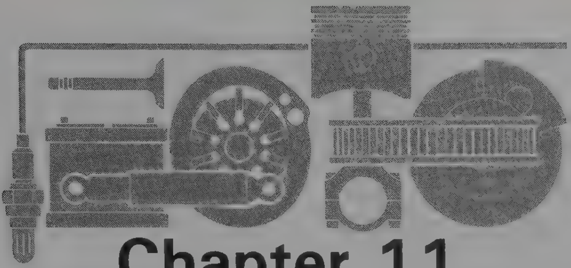
Remember: Regardless of age or condition, always treat your customer's car with real respect. Use fender and seat covers. Never rest tools on the top, hood, or any body section. Do not place your feet on the bumpers or lean against the body. Watch door panels when entering or leaving. When finished, wipe the steering wheel and check carefully for finger prints. These precautions, in good shops, are a matter of standard procedures.

KNOW THESE TERMS

Sintering, Locating lug, Sliding friction, Rolling friction, Cast bearing, Rebabbitting, Tin flash plate, Overplate, Barrier plate, Thumbnail oil groove, Parting edge, Radial pressure, Bearing cap, Elongate, Annular groove, Bowed crankcase, "Throw off" oil, Semi-finished insert, Line boring, Honed to size, Dirt impregnated, Lugging, Oil hole.

QUIZ - Chapter 10

1. Define the term friction bearing.
2. The cast babbitt bearing is widely used today. True or False?
3. The precision ________ ________ usually has a ________ back.
4. Name three popular bearing materials.
5. ________ flanges are used to control end play in the shaft.
6. Define bearing spread.
7. Bearing ________ assures a tight contact between the insert and housing.
8. Locating ____________ prevent the insert from turning.
9. A few nicks in the insert housing bore are not harmful. True or False?
10. Reversing or mixing bearing caps will cause the bores to become misaligned. True or False?
11. A bearing cap can be shifted out of alignment by using a thick wrench. True or False?
12. Blocks often ________, thus distorting the main bearing ________.
13. It is always permissible to mix bearing halves and to use the lower half in the upper bore. True or False?
14. All bearing inserts must have oil grooves. True or False?
15. An average bearing clearance would be around ________.
16. When journals are worn or reground, ________ inserts are required.
17. Describe a bushing.
18. Bearing journals must be ________, ________, and smooth.
19. A micro finish is the newest type of bearing material. True or False?
20. Finger prints on insert bearing surfaces can and do cause ________.
21. Snap inserts into place by shoving on the ________ ________ with your ________.
22. List three danger signals that could indicate imminent bearing failure.
23. Oil filters will always screen out all foreign particles. True or False?
24. What can cause poor lubrication? List four reasons.
25. List four assembly mistakes that will ruin the bearings.
26. List three operational (driving) faults that will cause bearing damage.
27. Describe five ways dirt, from external sources, can enter an engine after it has been placed in service.



Chapter 11

ANTIFRICTION BEARINGS

After studying this chapter, you will be able to:

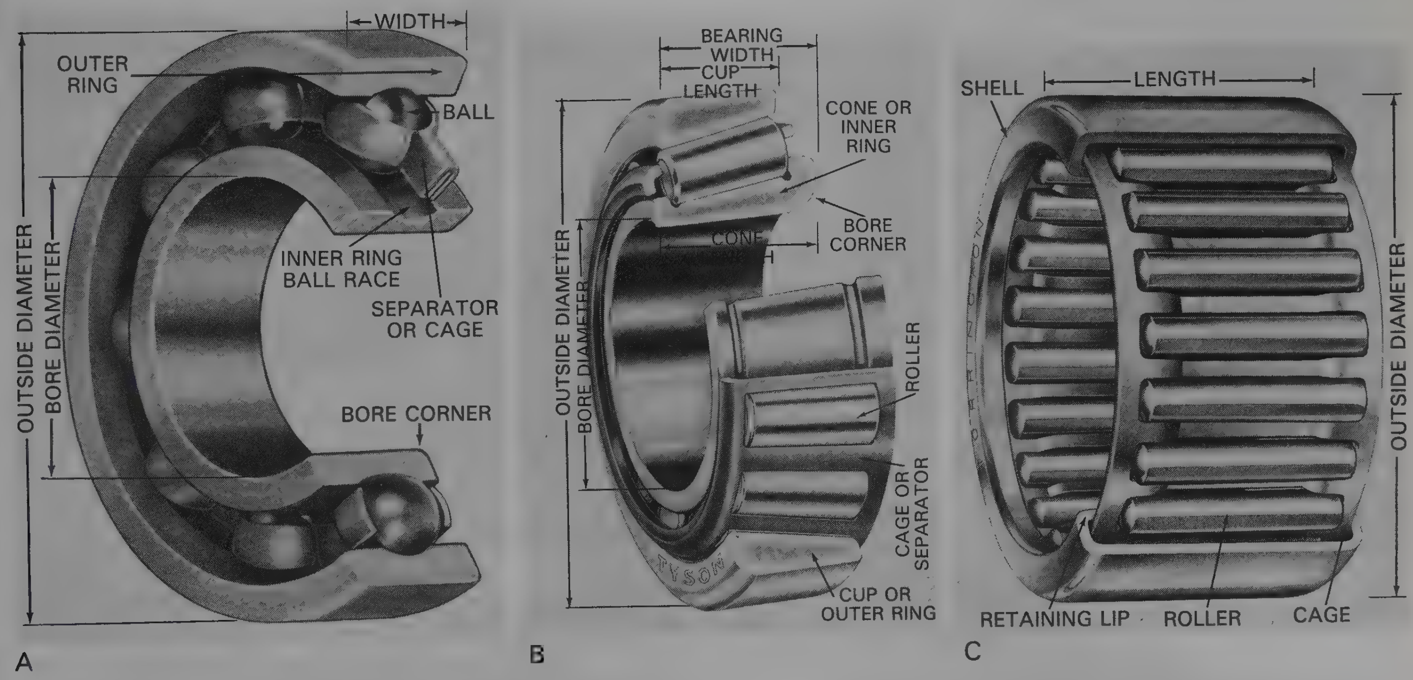
- ☐ List the different kinds of antifriction bearings.
- ☐ Explain the advantages of each type of antifriction bearing.
- ☐ Describe service procedures for antifriction bearings.

CONSTRUCTION

The antifriction type bearing utilizes rolling elements (balls or rollers) to reduce friction through rolling contact. In most applications, the rollers or balls are placed between inner and outer rings. The rolling elements are separated by a cage or separator, generally made of stamped steel. The cage prevents the elements from bunching and sliding against each other. In the case of separable (can be taken apart) bearings, the cage prevents the loss of the elements.

The balls or rollers, as well as the inner and outer rings, are hardened and ground to assure proper contact and clearance.

Needle bearings (long, thin rollers) often use only an outer shell. In some needle roller applications, the bore and shaft are hardened then ground and placed in direct contact with the rollers.



WIDTH
OUTER RING
BALL
INNER RING BALL RACE
SEPARATOR OR CAGE
BORE CORNER
OUTSIDE DIAMETER
BORE DIAMETER
A
BEARING WIDTH
CUP LENGTH
CONE OR INNER RING
BORE CORNER
CONE LENGTH
OUTSIDE DIAMETER
BORE DIAMETER
ROLLER
CAGE OR SEPARATOR
CUP OR OUTER RING
TYSON
B
SHELL
LENGTH
OUTSIDE DIAMETER
RETAINING LIP
ROLLER
CAGE
C

Fig. 11-1. Three types of antifriction bearings. A—Typical ball bearing construction. Note how cage keeps balls evenly spaced. (Nice) B—Roller bearing. This bearing uses tapered roller design. Outer ring is separate. (SKF) C—Caged needle bearing. Rollers in this bearing operate against outer shell and in direct contact with hardened, ground shaft surface. (Torrington)

THREE BASIC TYPES

Bearings are commonly divided into three types: BALL, ROLLER, and NEEDLE. Each type has certain applications it serves best. The ball bearing produces the least amount of friction, but for a given size, does not have the load carrying ability of the roller. All three types are used in automotive construction. Fig. 11-1 illustrates the three types. Learn the names of the parts.

LOADING DESIGN

Bearings are designed to handle RADIAL, THRUST, or a combination of both radial and thrust loads. Radial designs handle loads at right angles to the axis of the bearing. Thrust designs handle loads parallel to the axis. Combination designs handle loads from any direction. Fig. 11-2 shows the loading designs.

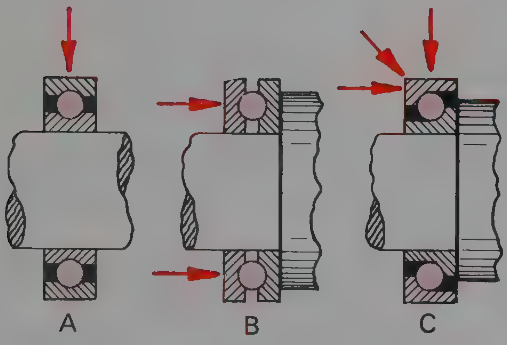


Fig. 11-2. Loading designs. A—Radial. B—Thrust. C—Combination radial and thrust. Arrows in color indicate direction of load.

VARIATIONS

There are many variations of the three basic types. Each different design attempts to meet a specific demand. The installation may call for light or heavy loads, high or low speeds, radial, thrust, or a combination loading. By understanding the problems involved and the type of bearing best suited, the mechanic will be greatly aided in all bearing work.

Some of the more common variations are the straight roller, spherical roller, tapered roller, deep groove ball, angular contact ball, multiple row, and self-aligning.

STRAIGHT ROLLER

The straight roller is designed to handle heavy RADIAL loads. In most designs, it will handle little or no thrust, Fig. 11-3.

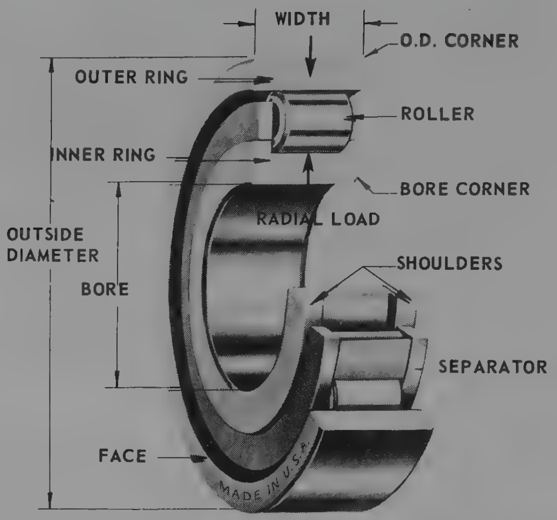


Fig. 11-3. Straight roller bearing designed for radial load only. (AFBMA)

SPHERICAL ROLLER

The rollers in this bearing are of curved or spherical shape. It will handle HEAVY radial loads and MODERATE thrust loads. It is self-aligning to a degree, Fig. 11-4.

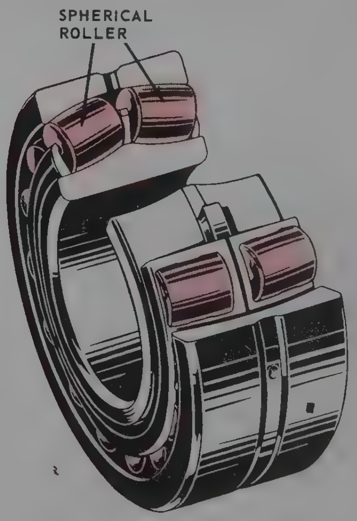


Fig. 11-4. Spherical roller bearing. Note "barrel" shape of rollers. (SKF)

TAPERED ROLLER

The tapered roller is the most widely used of the roller bearings as it will carry both HEAVY thrust and radial loads. The apex of the angles formed by both the rollers and raceways, if extended, would meet on a common axis. This allows the roller to follow the tapered raceways with no bind or skidding. Common

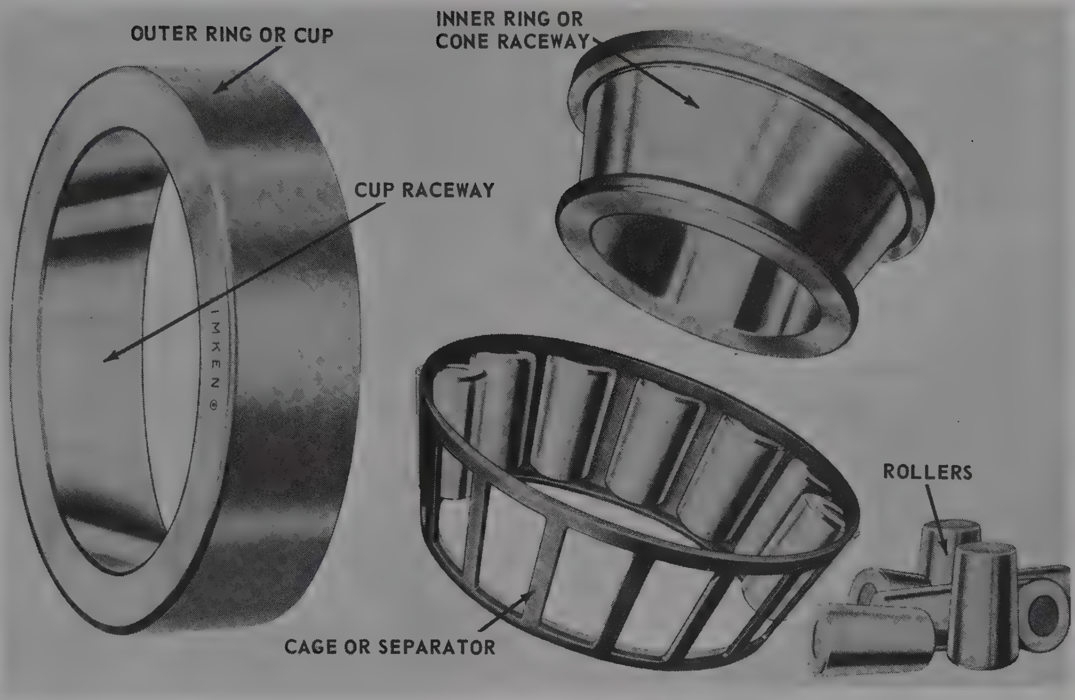

OUTER RING OR CUP
INNER RING OR CONE RACEWAY
CUP RACEWAY
IMKEN®
ROLLERS
CAGE OR SEPARATOR

Fig. 11-5. Tapered roller bearing parts. Once assembled, this particular bearing will have a separable outer ring but rollers, cage, and inner ring will be one unit.

practice is to secure the rollers to the cone with a steel cage. The cone raceway is indented to form a lip that keeps the rollers centered. The cup is then separable. Look at Figs. 11-1, B, and 11-5.

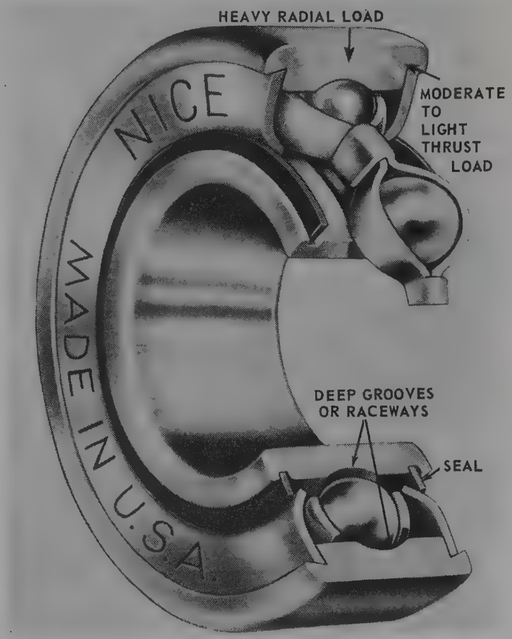

HEAVY RADIAL LOAD
MODERATE TO LIGHT THRUST LOAD
NICE
MADE IN U.S.A.
DEEP GROOVES OR RACEWAYS
SEAL

Fig. 11-6. Deep groove ball bearing. Note the use of seals on both sides.

DEEP GROOVE BALL

The deep groove ball bearing will handle HEAVY radial and MODERATE thrust loads. Neither the inner or outer ring is separable, Fig. 11-6.

ANGULAR CONTACT BALL

This ball bearing will handle both HEAVY thrust and radial loads. The balls are contained within a cage. Both inner and outer rings are separable, Fig. 11-7.

MULTIPLE ROW BEARING

Bearings can employ two or more rows of balls or rollers so that heavier loads, both radial and thrust, can be carried. They can also be designed to provide for thrust loads in BOTH directions, Fig. 11-8.

THRUST DIRECTION

You will note that several of the bearings shown will sustain thrust in ONE direction only. Thrust in the opposite direction would force the rings apart. By using two or more bearings, facing in opposite directions, thrust in either direction can be handled. See Fig. 11-9.

THRUST BEARING

The bearings shown in Fig. 11-10 are designed to handle THRUST forces only.

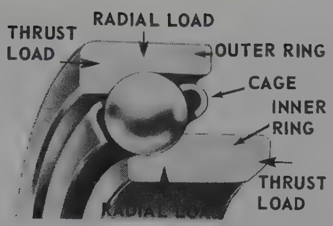

THRUST LOAD
RADIAL LOAD
OUTER RING
CAGE
INNER RING
THRUST LOAD
RADIAL LOAD

Fig. 11-7. Angular contact ball bearing. This type is often used as car front wheel bearings.

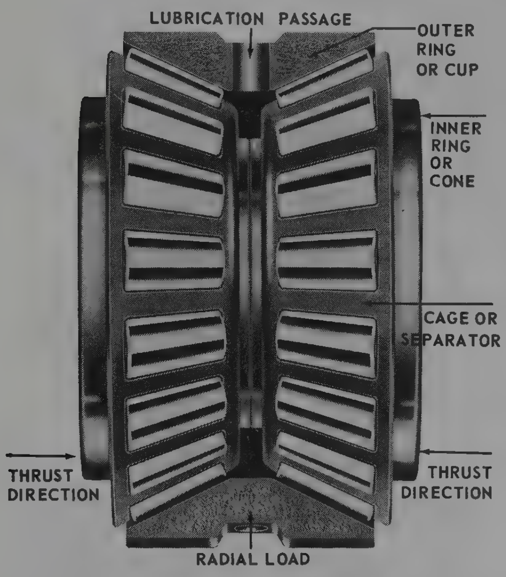

LUBRICATION PASSAGE
OUTER RING OR CUP
INNER RING OR CONE
CAGE OR SEPARATOR
THRUST DIRECTION
THRUST DIRECTION
RADIAL LOAD

Fig. 11-8. Double row, tapered roller bearing. The outer ring is one piece, the inner rings are separate. (Timken)

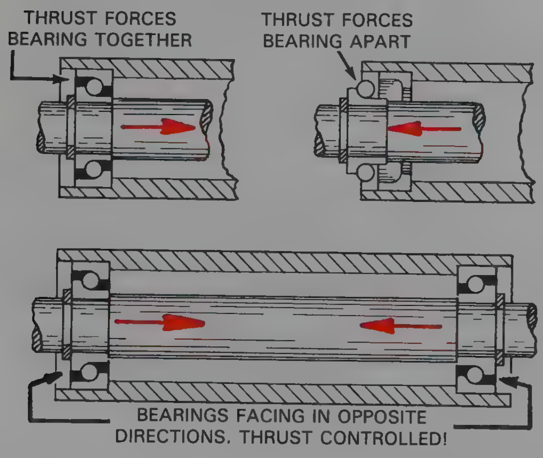

THRUST FORCES BEARING TOGETHER
THRUST FORCES BEARING APART
BEARINGS FACING IN OPPOSITE DIRECTIONS. THRUST CONTROLLED!

Fig. 11-9. By using two bearings, thrust in either direction is controlled. Arrows indicate thrust direction.

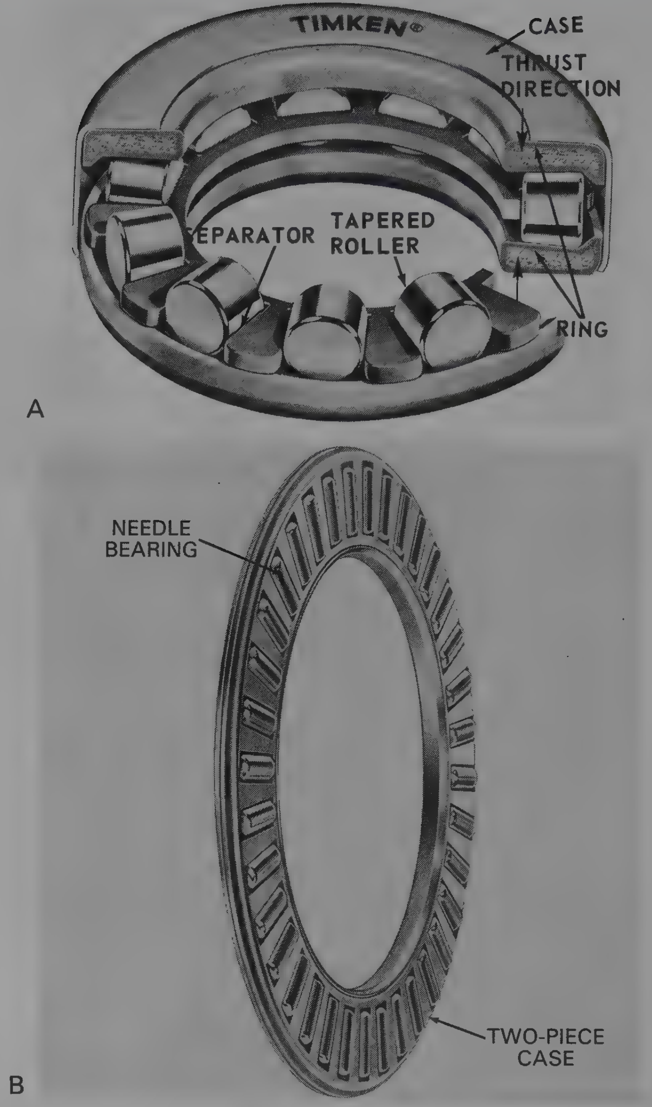

TIMKEN
CASE
THRUST DIRECTION
EPARATOR
TAPERED ROLLER
RING
A
NEEDLE BEARING
TWO-PIECE CASE
B

Fig. 11-10. A—Tapered roller thrust bearing. B—Needle thrust bearing. Note how two-piece case also acts as needle separator. (Timken, Torrington)

SELF-ALIGNING BEARINGS

When there is a possibility, or in some instances, a desirability, of permitting either housing or shaft misalignment during operation, a self-aligning bearing is used. This bearing will allow a degree of tilt without distorting the bearing elements. Both internal and external self-aligning bearings are shown in Fig. 11-11.

BEARING IDENTIFICATION

All bearings are marked with a part number for ease of replacement. The number is usually on the face of the rings. If necessary, replacement bearing size can be checked by careful measurement.

BEARING SEALS

Bearings can be open on both sides or sealed on one or both sides. Sealing on one side is often used to help confine lubricant and to prevent the entry of dirt. When both sides are sealed, the bearing is lubricated during

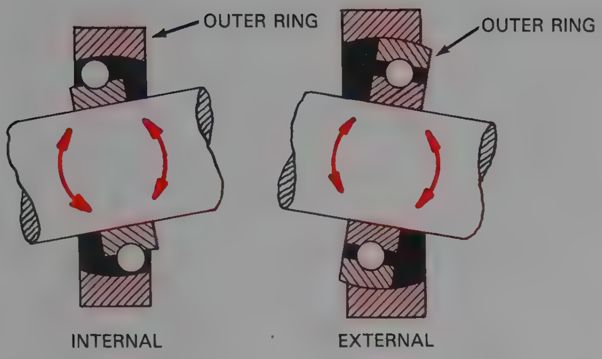


Fig. 11-11. Internal and external self-aligning bearings. Note how shaft is free to tip. External design will handle heavier loads as ball has a wider contact area with outer ring.

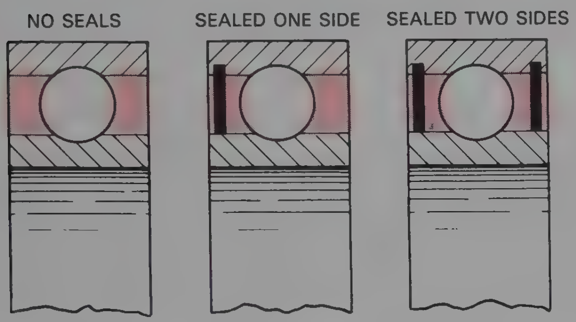


Fig. 11-12. Bearing seal construction.

assembly and no lubricant can be added in the field. See Fig. 11-12.

REMOVING BEARINGS

Prior to pulling bearings, clean the surrounding area to prevent contamination.

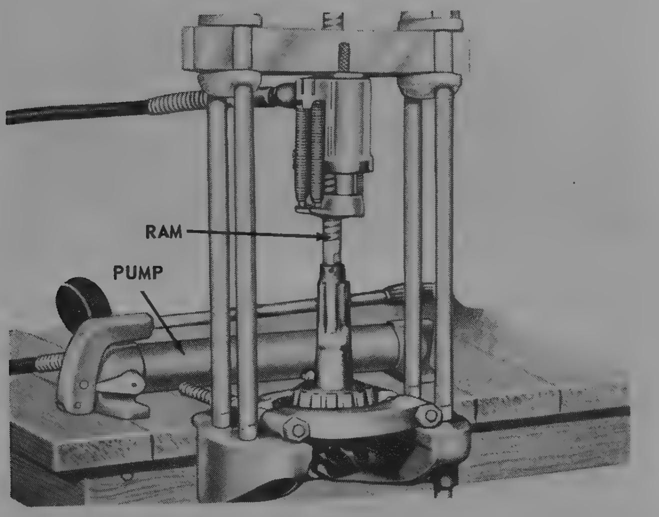


Fig. 11-13. Removing differential pinion shaft bearing with hydraulic puller. (O.T.C.)

Bearings are generally best removed with mechanical or hydraulic pushing or pulling tools. They exert a heavy and STEADY force, Fig. 11-13.

Without such pullers, or where their use is impossible or undesired, a suitable hammer and soft steel drifts, sleeves, and cup drivers will handle many jobs.

Any attempt to pull or install a bearing by exerting force on the free (not tight) ring is apt to chip the balls or rollers. The ring itself could crack and fly apart. There are some instances, as you will see later, that require force on either the free ring or rolling elements. However, WHENEVER POSSIBLE, EXERT THE FORCE ON THE TIGHT RING ONLY.

Fig. 11-14 shows both the right and wrong way of applying pulling force. Note that in A, the supporting puller plate rests on the free outer ring. In B, the plate supports the inner ring only, thus avoiding damage to the outer ring and rolling elements.

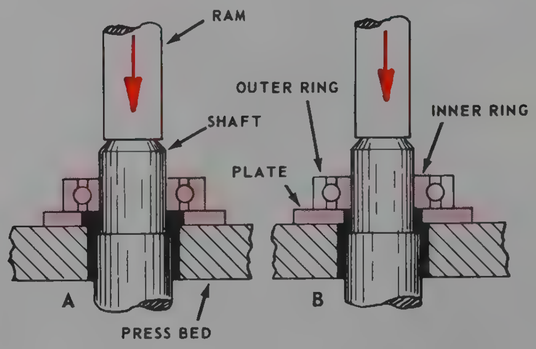


Fig. 11-14. Pulling setups. A—Wrong as force is applied through free outer ring and rolling elements. B—Correct. Force is through tight ring only.

WHEN INNER RING CANNOT BE GRASPED

Occasionally, the bearing inner ring is pressed against a shoulder that is as wide or wider than the ring. In the case of the tapered roller bearing, a special segmented (made in parts) adapter ring can be used. It applies the pulling force to the ends of the rollers while forcing them against the cone. This allows the bearing to be removed without damage, Fig. 11-15.

Another type of puller, especially adapted for axle shaft bearing work, is pictured in Fig. 11-16. A split sleeve, with pulling rings, is used. The axle shaft passes up through a section of tubing. The puller sleeve grasps both bearing and tubing. The top section of the tubing is fastened to a heavy plate on the bed of the press. As pressure is applied to the shaft end, it is forced through the tube to pull the bearing. Note that the entire bearing is shrouded or shielded to protect the operator from flying parts if the bearing should explode. This puller will remove both tapered roller and ball bearings, Fig. 11-16.

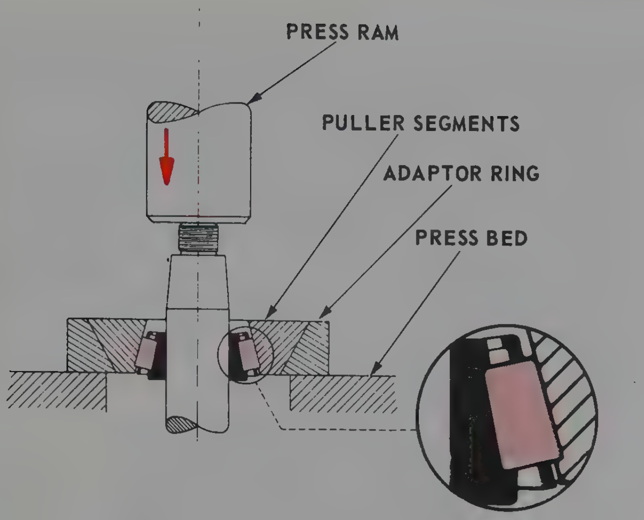


Fig. 11-15. Pulling bearing by applying pressure through rollers. Magnified portion at lower right shows how end of roller is grasped by puller segments. (Timken)

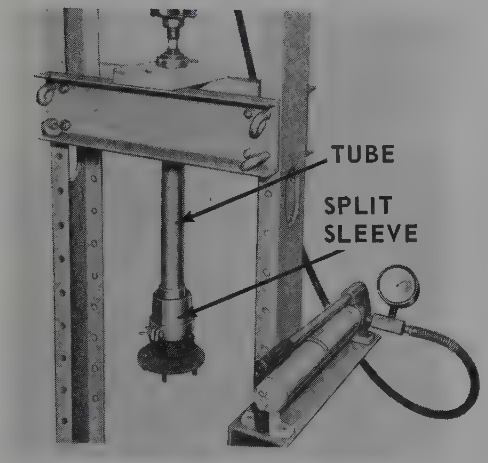


Fig. 11-16. Removing axle shaft bearing with special puller.

WHEN BEARING CANNOT BE GRASPED

There are instances in which a retaining plate or dust shield is so close to, or surrounding, the bearing that it is impossible to grasp it. In these cases, you must grind away a portion of the inner ring (protect shaft with a metal sleeve). Cut out the cage and remove the elements. The outer ring can then be removed, exposing the inner ring for grasping.

Unhardened retaining rings are sometimes used to hold bearings in place. They are best removed by notching with a sharp chisel. This will loosen them enough for easy removal. See Fig. 11-17.

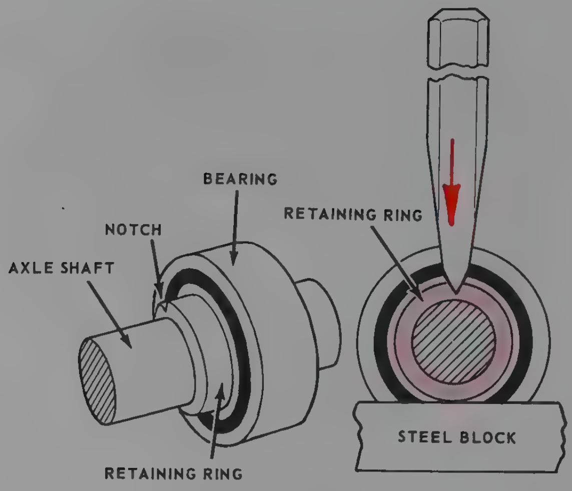


Fig. 11-17. Removing bearing retaining ring by notching with a chisel.

Inner bearing rings can also be removed by partial grinding or by cutting part way through with an acetylene cutting torch. WRAP THE SHAFT, ON BOTH SIDES OF THE BEARING, WITH WET CLOTHS TO PREVENT HEATING. CUT ONLY PARTWAY THROUGH. The ring is then squeezed tightly in a vise and struck with a hammer where indicated by the arrows in Fig. 11-18. This will crack the ring and allow it to be pulled. WEAR SAFETY GOGGLES WHEN STRIKING BEARING PARTS.

Always pull bearings whenever possible. AVOID GRINDING AND CUTTING WITH A TORCH, UNLESS ABSOLUTELY NECESSARY.

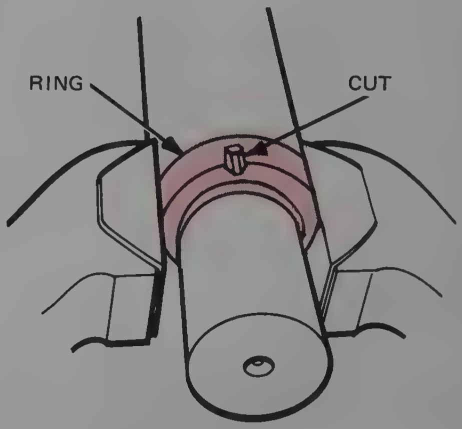


Fig. 11-18. Bearing inner ring partially cut and then squeezed in a vise. Strike with a hammer where indicated by arrows. (Federal-Mogul)

KEEP BEARING PARTS TOGETHER

When a separable bearing is removed, keep the parts together. Under no circumstances should bearing elements be mixed.

GENERAL RULES FOR BEARING REMOVAL

1. Exert force, where possible, on the tight ring.
2. Use pullers of the correct size and shape.

3. Mount puller to exert force in a line parallel to the bearing axis.
4. Use unhardened, mild steel drifts and sleeves.
5. Never strike the outer or free ring.
6. Use care to avoid damage to the shaft or housing.
7. If necessary to hammer a shaft, use a brass, lead, or plastic hammer.
8. Keep all parts of one bearing together.

WATCH OUT!

PULLING BEARINGS, BOTH WITH PRESSURE OR STRIKING TOOLS, CAN BE A DANGEROUS OPERATION. BEARINGS UNDER SUCH PRESSURE CAN SHATTER AND SEND PIECES FLYING OUTWARD WITH LETHAL FORCE. WHENEVER POSSIBLE, SHIELD THE BEARING. WEAR SAFETY GOGGLES. KEEP OTHER PERSONNEL AWAY FROM WORK AREA.

CLEANING BEARINGS

When the bearing is removed, wipe off all surplus grease or oil. Soak in kerosene or cleaning solvent. A regular cleaning tank with tray and solvent hose is ideal. If none is available, a clean bucket will suffice, Fig. 11-19.

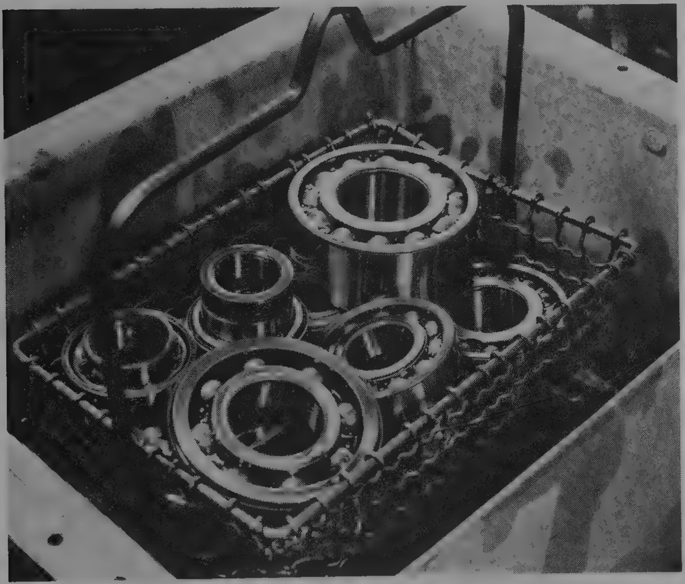


Fig. 11-19. Tray full of bearings being placed in kerosene.

CAUTION!

NEVER USE GASOLINE OR OTHER VOLATILE FLUIDS FOR CLEANING. THEY ARE ROUGH ON HANDS AND WILL IGNITE READILY. DO NOT USE CARBON TETRACHLORIDE AS IT PRODUCES POISONOUS FUMES.

While some bearings are soaking, brush each in turn with a nylon bristle brush and blow out the worst of the grease. Continue soaking and brushing until the bearing looks clean. Blow the bearing out again. If any sign of grease is visible, soak, brush, and blow out once more.

DO NOT SPIN!

NEVER SPIN A BEARING WITH AIR PRESSURE. NOT ONLY WILL IT DAMAGE THE BEARINGS, IT CAN ALSO BE DANGEROUS. WHEN THE OUTER RING OF A SEPARABLE BEARING IS REMOVED, THE ROLLING ELEMENTS ARE HELD TO THE CENTER RING WITH THE CAGE. IF THE CAGE AND ROLLERS ARE SPUN, THE TREMENDOUS CENTRIFUGAL FORCE GENERATED CAN CAUSE ONE OR MORE ELEMENTS TO FLY OUTWARD WITH VIOLENT FORCE.

When certain the bearing is CLEAN, rinse in a container of CLEAN kerosene and blow dry. Look at Fig. 11-20.

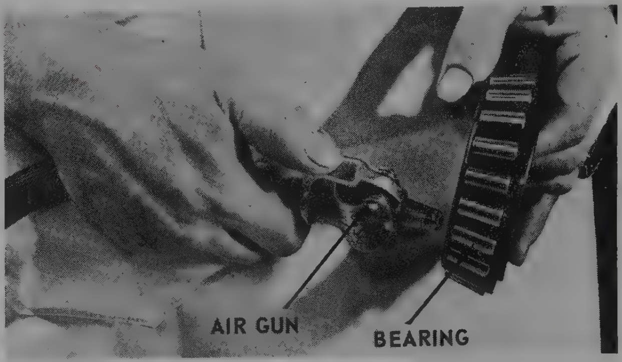


Fig. 11-20. Using clean, dry air, blow bearing dry. Do not allow bearing to spin. (Timken)

USE CLEAN, DRY AIR

Most air compressor systems are equipped with a filter and moisture trap. Service them often. Directing a stream of air into a white cloth will show if dirt or oil is present.

DO NOT WASH SEALED BEARINGS

When a bearing is factory packed and completely sealed on both sides, it must not be washed. Wipe off the outside with a clean, dry cloth. Washing will dilute the lubricant and lead to early failure.

CLEAN WORK AREA IS A MUST

Once the bearings are cleaned and dried, take them to a CLEAN work area. It is a good idea to reserve

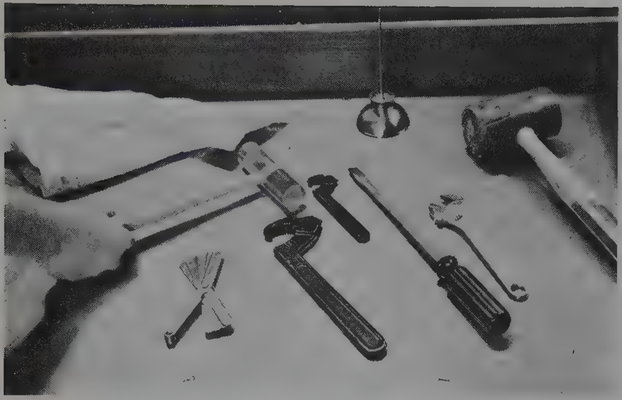


Fig. 11-21. Ideal bearing work area. (SKF)

a section where this assembly area will be free of dusty air, grinding machines, and steam cleaning moisture. Fig. 11-21 pictures an ideal work section.

BEARING DEFECTS

Prior to discussing checking procedures, it is wise to familiarize yourself with some of the most common bearing defects. Refer to Fig. 11-39.

As is the case with friction bearings, DIRT is the number one enemy of ball and roller bearings. It will cause scratching, pitting, and rapid wear. Other common defects include spalling, brinelling, overheating, cracked rings, broken cages, damaged seals, and corroded areas.

SPALLING

Foreign particles, overloading, and normal wear over an extended period can lead to spalling. Spalling starts when tiny areas fracture and flake off. These small flakes are carried around in the bearing causing more flaking. Advanced flaking or spalling will produce large craters, Fig. 11-22.

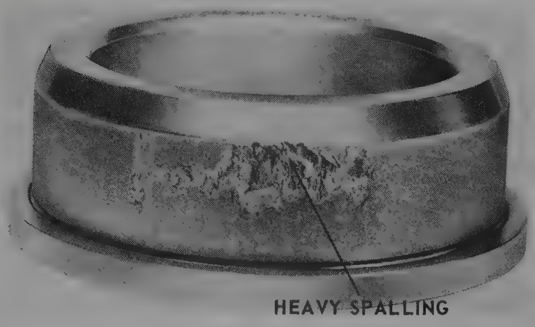


Fig. 11-22. Badly spalled inner ring. (AFBMA)

BRINELLING

Brinelling is the term used to describe a series of dents or grooves worn in one or both rings. The grooves run across the raceway and are usually spaced at regular intervals. Once brinelling starts (often from inadequate lubrication) a fine reddish iron oxide powder is formed. As the powder is carried around, it increases the wear rate. Fig. 11-23 shows a badly brinelled outer shell.

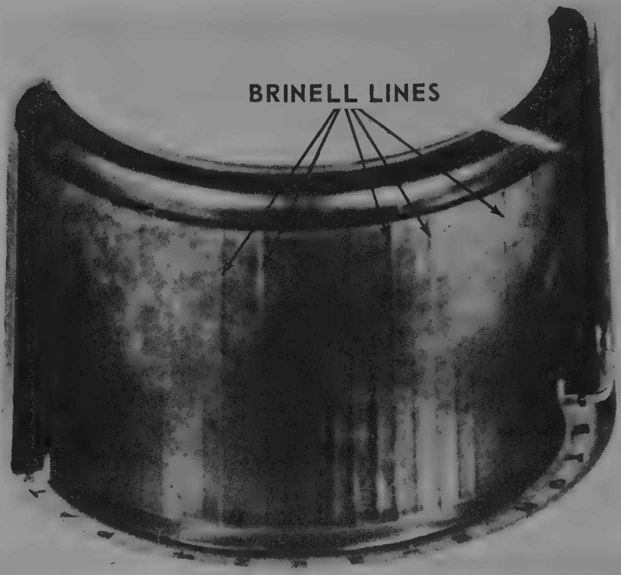


Fig. 11-23. Brinelled needle bearing shell.

OVERHEATING

Overheating will break down the physical properties of the bearing and cause rapid failure. Lack of lubrication, improper lubrication, and poor adjustment are the principal causes. The bearing rings and rolling elements which have been overheated will have a blue or brownish-blue discoloration. See Fig. 11-24.

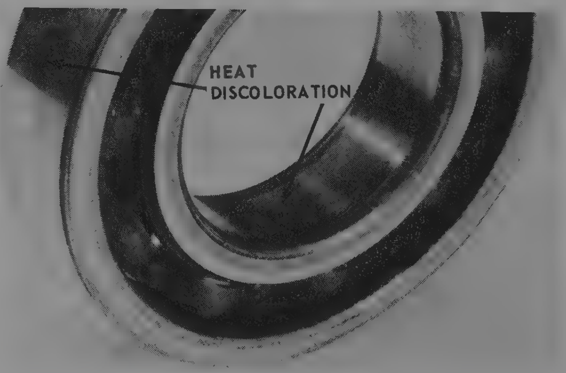


Fig. 11-24. Overheated bearing. Note discoloration.

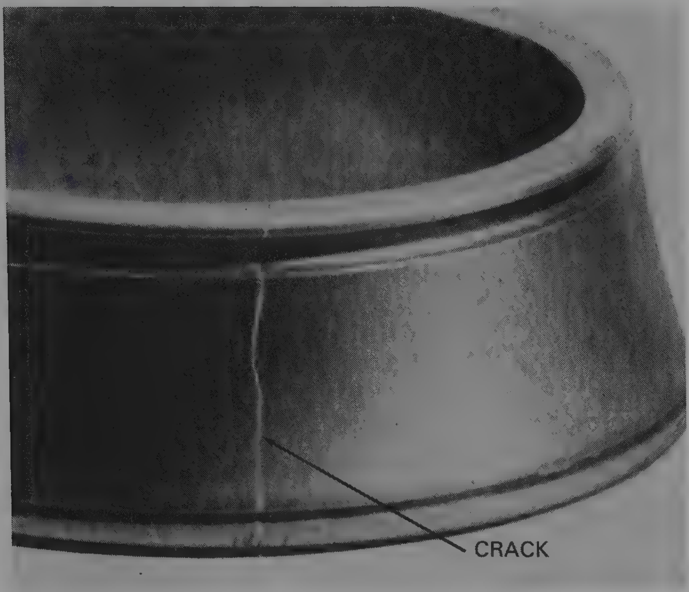


Fig. 11-25. Cracked inner ring.

CRACKED RINGS

One or both rings may be cracked. Improper removal or assembly techniques and wrong bore or shaft size are common causes. Look at Fig. 11-25.

BROKEN OR DENTED CAGE

Improper removal and assembly procedures will often result in a dented or broken cage. Pieces of dirt and metal chips will also cause cage breakage. Refer to Fig. 11-26.

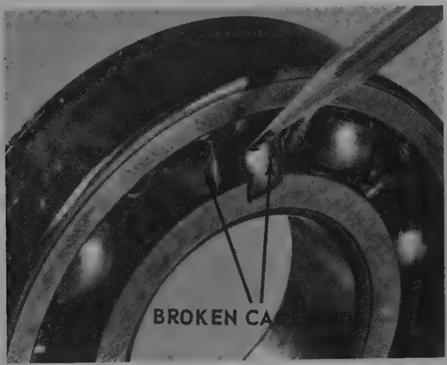


Fig. 11-26. Broken cage.

DENTED SHIELDS

As with a broken cage, careless assembly often produces dented shields. This could also damage the cage as well as cause binding and lubricant loss. See Fig. 11-27.

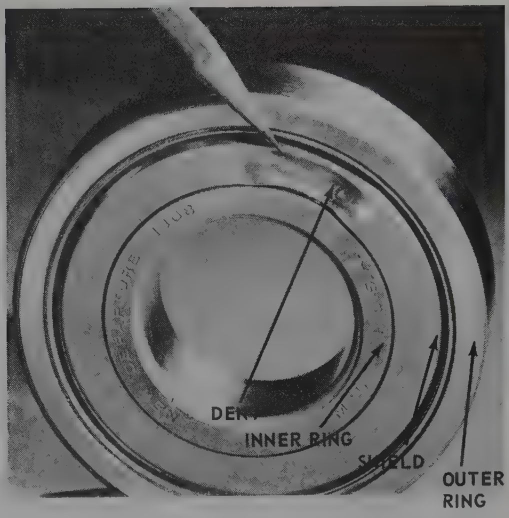


Fig. 11-27. Badly dented bearing shield or seal. (New Departure)

CORROSION

The entry of moisture (often from air hose), wrong or contaminated lubricant, or storage near corrosive vapors can produce corrosion in the bearing. A bearing remaining static (not being rotated) for an extended time, often corrodes, Fig. 11-28.

DIRT WEAR

If the dirt is very fine, it will have a lapping effect (removal of surface metal through fine abrasive action)

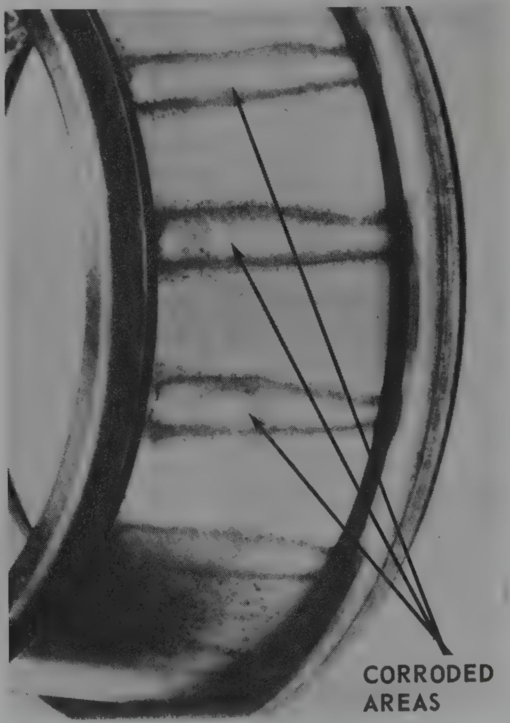


Fig. 11-28. Corroded bearing.

that will leave the rolling elements and raceways with a dull, matte (nonreflecting) finish. Larger dirt particles will produce scratches and pits.

ELECTRICAL PITTING

Electric motor or generator bearings are sometimes pitted by the passage of current (from an internal short or from static electricity) through the bearing. The minute arcing produces numerous tiny pits. Fig. 11-29 illustrates the effect of electrical pitting, dirt, corrosion, and poor lubrication on rollers.

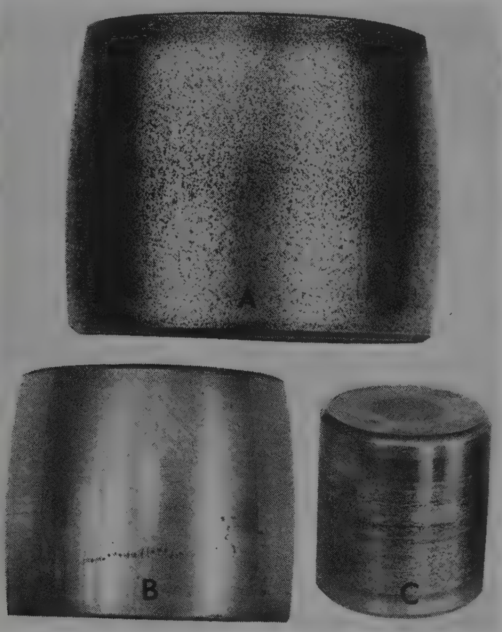


Fig. 11-29. Roller damage. A—Corrosion. B—Electrical pitting. C—Poor lubrication and dirt. (SKF)

SOME LOOSENESS IS NORMAL

A new bearing often feels rather loose so do not assume looseness as a sign of wear. When either raceways or rolling elements are worn enough to produce looseness, it will be evident by examining the surfaces. One or more of the conditions mentioned above will be visible.

BEARING INSPECTION

When inspecting nonseparable bearings, place the fingers of one hand through the center ring, Fig. 11-30. Rotate the outer ring with the other. The bearing should revolve smoothly with no catching or roughness. If either condition is present, rinse and blow dry again. If the symptoms still persist, discard the bearing. Also check for signs of overheating and wear on the outer surfaces of both rings. A bearing that has been loose in the bore, or on the shaft, will have highly polished areas showing.

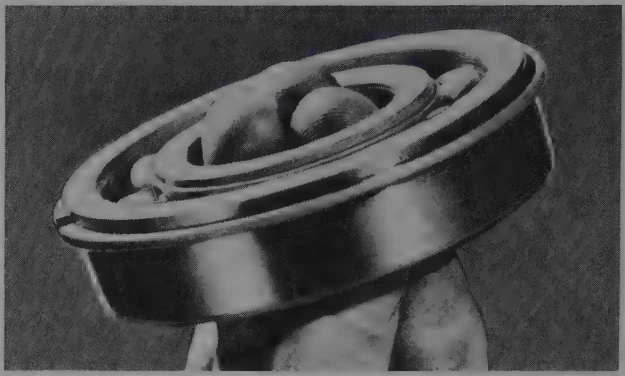


Fig. 11-30. Holding bearing for inspection.

For separable bearings, carefully inspect the raceways and rolling elements. They should be absolutely smooth and free of heat discoloration. Inspect EACH ball or roller. Only one or two may be damaged. When satisfied as to condition, place the elements together. While forcing them together, rotate the bearing. The operation should be smooth.

When revolving bearings, do so a number of times. A single damaged ball or roller may not "catch" the first few times around. When checking thrust bearings, place one side on a solid surface. Press down on the other with the heel of your hand. While maintaining pressure, rotate. KEEP HANDS CLEAN, DRY, AND AWAY FROM RACEWAYS AND ROLLING ELEMENTS. See Fig. 11-30.

DO NOT SAVE ONE PART

If any part, outer or inner ring, or rolling elements are damaged, discard the ENTIRE bearing. Never replace a part of a bearing.

Before discarding, write down the part number. It is a good idea to wire the parts together and keep for comparison with the replacement bearing. Mark as DEFECTIVE.

BEARING LUBRICATION

If the bearing will be placed into service at once, it may be packed with the proper grease or it may be oiled, depending upon the need. Cover with a clean cloth until ready to install. If it will be stored for a few days, coat with oil and place in a clean box or container. IMMEDIATELY FOLLOWING INSPECTION, COAT WITH THE DESIRED LUBRICANT TO PREVENT THE FORMATION OF RUST. Look at Fig. 11-31.

If the bearing will be stored for an extended period, coat with light grease. Wrap in oilproof paper and place

Fig. 11-31. Bearings cleaned, oiled, and placed in protective container.

in a clean box. Be sure to identify the bearings to prevent opening a number of them when looking for a specific one at some future date. When coating bearings for storage, rotate to insure proper penetration and coverage, Fig. 11-32.

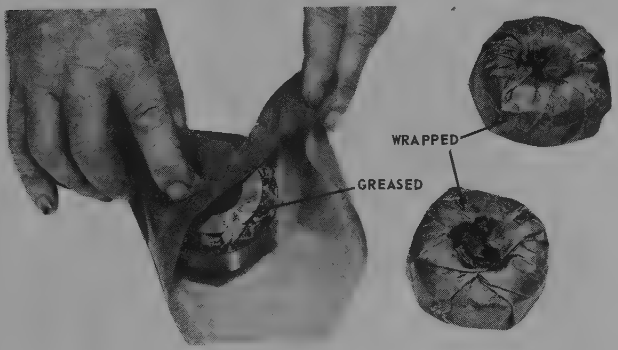


Fig. 11-32. Bearings greased and wrapped for extended storage.

PACKING WITH GREASE

When a bearing calls for grease (specific recommendations for each type will be given in section to which they pertain), use a bearing packer. If no packer is available, place a "gob" of grease on the palm of one hand. Your hands must be clean and dry. With the other, press the edge of the bearing into the grease (near edge). Repeat this until grease flows out the top. Move around to different sections until the bearing is fully packed. Separable rings should be coated also. See Fig. 11-33.

PROTECT LUBRICANTS

All grease and oil in the shop should be kept in clean containers and kept tightly covered when not in use. When opening, wipe dirt off lid and avoid dusty areas. An open can of grease near a grinder or cutting torch is an open invitation to disaster.

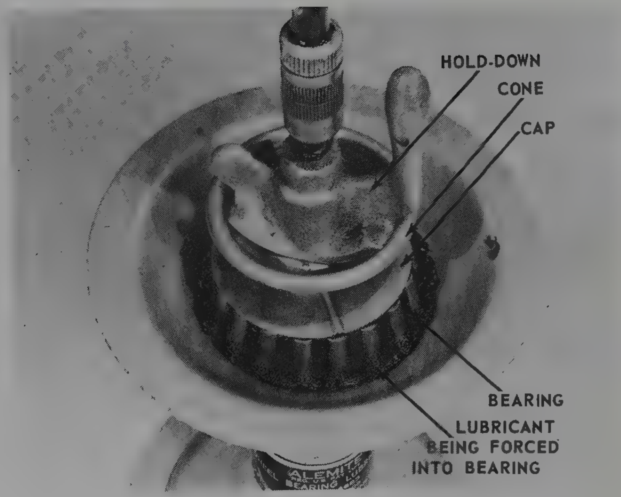


Fig. 11-33. A bearing packer is fast and efficient. (Timken)

CHECK SEALS

If any oil or grease seals are related to the job at hand, inspect them. If necessary, replace the seals at this time. In some instances, seals must be installed after the bearings.

BEARING INSTALLATION

Bearing installation calls for care and intelligent use of tools. Many otherwise good jobs have been ruined by careless installation.

MAKE CERTAIN YOU HAVE THE CORRECT BEARING

Bearings are often similar (but not exact) in type and size. Before attempting installation, make certain you are installing the correct one. Be especially careful with new replacement bearings. Check numbers and measurements.

CLEAN BORES AND SHAFTS

Clean bearing housing bores and shafts thoroughly. Remove any nicks or burrs with a fine file. Be careful not to file a flat spot. Following filing, polish with very fine emery or crocus cloth. On a shaft where the inner ring is designed to walk (creeping movement around shaft), inspect carefully. Polish if necessary. If the counterbores or press-fit shaft areas are worn from ring slippage, do not center punch or knurl (crosshatch pattern pressed into metal) as an attempt to increase size. Such procedures will only result in failure as the bearing, under load, will quickly flatten these raised areas. The area should be built up by metallizing (spraying molten metal onto shaft) and then ground to the correct

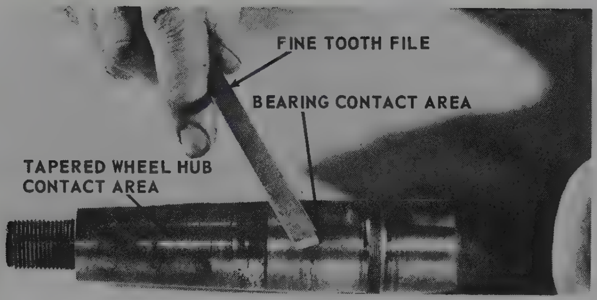


Fig. 11-34. Removing burrs from axle shaft bearing area with a fine tooth file.

size. Watch for dirt in threads, splines, and other areas. Look at Fig. 11-34.

USE LUBRICANT TO EASE ASSEMBLY

The use of a thin film of oil or micronized (finely powdered) graphite will ease installation, prevent corrosion around ring contact area, and facilitate removal at some future date. See Fig. 11-35.

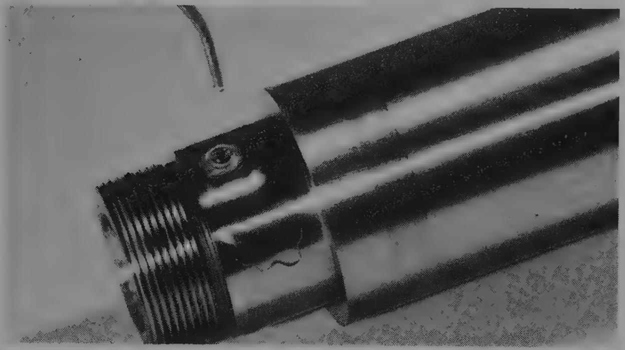


Fig. 11-35. Use lubricant to facilitate assembly.

HEAT AND COLD HELPS

In difficult assembly jobs, primarily large bearings, place the outer ring in dry ice or in a deep freeze. This will reduce the diameter and help installation. Inner rings can be heated (NEVER ABOVE 275°F or 135°C) in clean oil or special electric oven. Use a thermometer. Never heat bearings with a torch. Follow manufacturers' instructions. See Figs. 11-36 and 11-37.

POSITION PROPERLY AND START SQUARELY

After determining correct installation position (do not press on backwards or fail to position any retainers or snap rings that must go on first), start the bearing or ring with your fingers. Attach puller or set up in press and force bearing into place. MAKE CERTAIN IT GOES ON SQUARELY AND TO THE FULL DISTANCE REQUIRED. Apply pressure, whenever possible, on the tight ring. As in pulling, observe safety precautions.

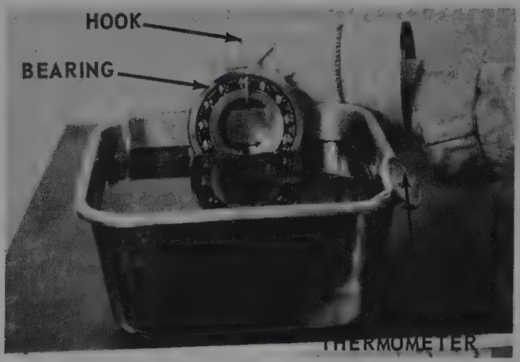


Fig. 11-36. Heating a bearing in oil. Hook keeps bearing from touching bottom of container.

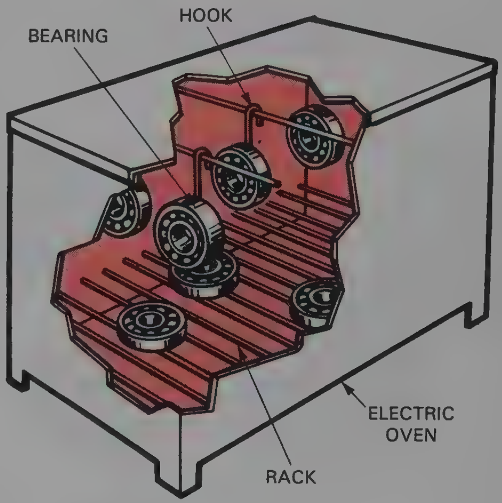


Fig. 11-37. One type of electric bearing oven. Note that bearings are placed on racks or suspended with hooks. Do not put them in direct contact with heat source. Follow manufacturers' instructions when operating. (Federal-Mogul)

SIMPLE TOOLS WILL OFTEN SUFFICE

If regular pressing tools are not available, simple driving tools will handle many jobs in a satisfactory manner. Make sure they are clean. Strike the tight ring only. Use soft steel tools. Brass tools tend to mushroom and chip, thus contaminating the bearings.

SHAFT AND HOUSING BORES MUST BE TRUE

A sprung shaft or bent housing will cause the bearing to operate in a distorted position, greatly shortening its life. For those jobs in which the bearing failed in a short time, despite proper installation, lubrication, and adjustment, always check shaft and housing for any warpage or other misalignment.

BEARING ADJUSTMENT

Some bearings require adjustment after installation. Proper adjustment depends on the application. Some require a specific amount of free play. Others require preloading (placing bearing under pressure so that when a driving force is applied to parts, they will not spring out of alignment). As the various service operations are described through the book, general adjustment recommendations will be given.

GENERAL RULES FOR BEARING INSTALLATION

1. Clean all contact surfaces and remove burrs and nicks.
2. Install parts that precede bearing.
3. Lubricate for easy installation.
4. If heat is required, do not exceed 275°F or 135°C.
5. Start bearing squarely.

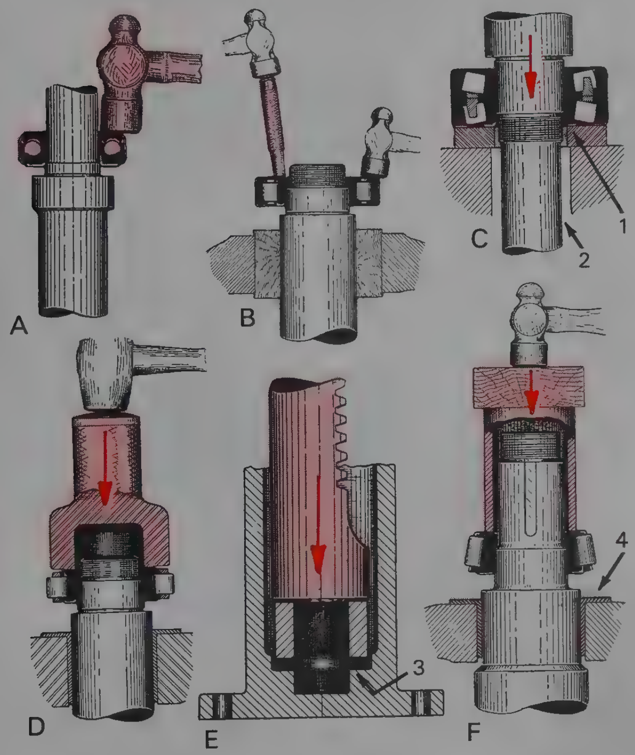


Fig. 11-38. Bearing installation hints. A—Do not strike bearing with a hammer. B—Do not use wide punches on bearings. C—Do apply force to tight ring (1) and have clearance (2) for shaft. D—Use driver with smooth, square cut ends that strike tight ring. E—Clean bearing ring recess (3) and force ring to full depth. F—Block placed on open pipe driver allows driving force to be centralized. Use protective vise jaw covers (4). (AFBMA)

6. Align tools so that bearing will be forced on squarely.
7. For driving tools, use soft steel.
8. When possible, avoid applying pressure through balls or rollers.
9. If a vise is needed, use protective jaw covers.
10. Driving tools must have smooth, square cut ends.
11. Do not mar shaft or bore surfaces.
12. Use safety precautions.
13. Press on the full distance required.

Fig. 11-38 illustrates a few do's and don'ts regarding bearing assembly.

SUMMARY

Bearings can be divided into three basic types: the BALL, ROLLER, and NEEDLE. The ball and roller bearing usually consists of an inner and outer ring with the rolling elements placed between them and positioned with a cage or separator. The needle bearing can use an outer shell, or can be placed in direct contact with a hardened and ground bore and shaft.

Bearings are designed to carry either straight thrust, radial, or combination loads.

The straight, spherical, and tapered roller, deep groove ball, angular contact ball, and self-aligning of both types, are the common variations.

Bearings are marked with a part number.

Bearings are often sealed on one or both sides. Never wash bearings sealed on both sides.

Hydraulic and mechanical pulling or striking tools can be used to remove bearings. All must be used with care. If available, hydraulic and mechanical pullers are recommended.

Pull bearings, whenever possible, by the ring that is tight. Special tools are available for pulling by exerting pressure through the balls or rollers. Avoid the use of heat. Do not mar bore or shaft surfaces. When bearing is removed, if separable, keep all parts together.

Clean bearings in kerosene. Blow dry. Rinse in fresh kerosene and blow dry again. Do not spin the bearing. Air should be clean and dry. Working in a clean area, inspect bearing, Fig. 11-39. If satisfactory, oil or pack with grease at once. Keep covered until ready to install. Rejected bearings may be kept for size comparison with replacements, but MARK them as REJECTS.

Scratched, pitted, spalled, brinelled, corroded, cracked, and overheated bearings, plus those with damaged cages or dented shields MUST be REJECTED. Never replace one part of a bearing.

Keep all lubricants covered when not in use. A bearing packer is handy for lubing with grease.

Replace defective grease or oil seals. Clean bore and shaft. Remove burrs and install any parts that must precede bearing.

Lubricate bearing seat area. Position bearing correctly and start by hand. Pull, press, or drive bearing fully

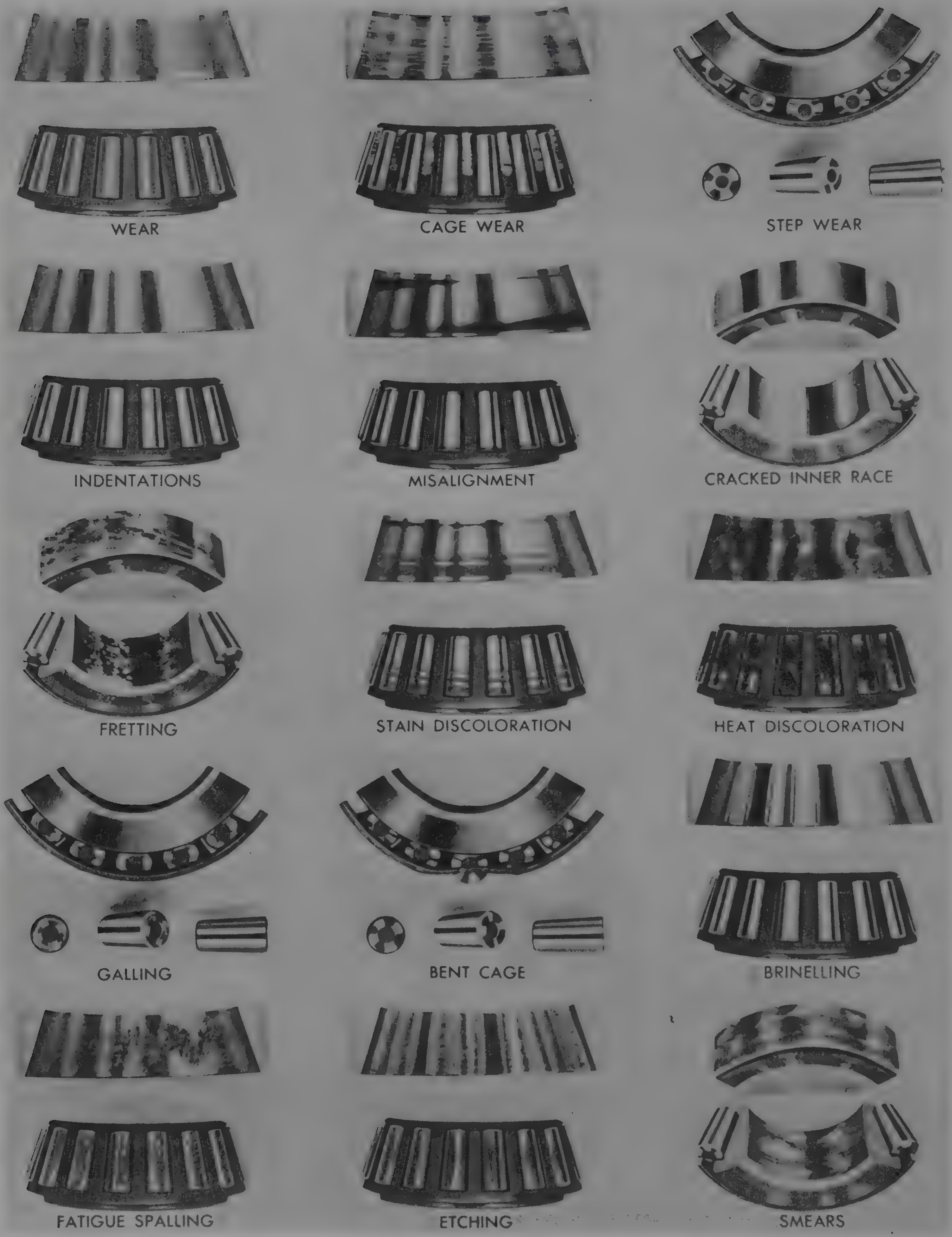

WEAR
CAGE WEAR
STEP WEAR
INDENTATIONS
MISALIGNMENT
CRACKED INNER RACE
FRETTING
STAIN DISCOLORATION
HEAT DISCOLORATION
GALLING
BENT CAGE
BRINELLING
FATIGUE SPALLING
ETCHING
SMEARS

Fig. 11-39. Some common roller bearing defects. Bearings showing these signs must be discarded. (Cadillac)

into place, keeping square at all times. Do not damage shaft or bore. Installation tools must be spotlessly clean. In difficult assembly jobs, the use of both heat (carefully controlled) and cold will ease installation.

If necessary, carefully adjust bearing.

SUGGESTED ACTIVITIES

1. Secure a number of damaged ball and roller bearings. Clean and inspect each one. Identify the cause of rejection. Try to find one good example of each typical defect.
2. Remove a bearing. Clean it properly. Inspect and pack with grease. Install the bearing following all recommendations.
3. Determine, as closely as possible, the exact number of ball, roller, and needle bearings used in a specific car. Count them in ALL areas: clutch, transmission, drive line, rear end, wheels, steering, pumps, motors, and other accessories.

HONESTY!

Unfortunately, many car owners feel (with justification in some cases) that automotive repair centers are not honest, that they often "pad" ~~mechanics~~ time, charge for parts not installed, and perform repairs that were unnecessary.

There is no doubt that these things do happen occasionally. The importance of COMPLETE HONESTY, on the part of the mechanic and garage, cannot be overemphasized. Customer relations are vital. They can make or break a business. ALWAYS give an EXACT record of labor. Perform ONLY REQUIRED repairs (if you encounter some essential repair not covered in an estimate, consult with customer before proceeding). Charge ONLY for parts ACTUALLY INSTALLED.

If this basic foundation of good business, and good living, practice is scrupulously followed, you will earn the respect and trust of your customers. Remember that there is no advertisement more effective than a SATISFIED customer.

KNOW THESE TERMS

Antifriction bearing, Cage, Ball bearing, Needle bearing, Roller bearing, Radial loading, Thrust loading, Raceway, Spalling, Brinelling, Bearing packer, Bearing oven, Etching, Fretting, Galling, Bore diameter, Outside diameter, Shell, Cup driver, Bearing axis.

QUIZ - Chapter 11

1. __________, __________, and __________ bearings are used in automotive construction.
2. Name three bearing load designs.
3. List three types of roller bearings.
4. The deep groove ball bearing will handle HEAVY thrust loads. True or False?
5. What advantage is offered by the self-aligning bearing?
6. Never __________ a bearing sealed on both sides.
7. Why are hydraulic or mechanical pullers generally superior to striking tools for bearing work?
8. Always apply pulling force to the free ring. True or False?
9. Under some circumstances, it is permissible to apply pulling pressure through the rolling element. True or False?
10. Bearings, under pulling pressure, can literally explode. True or False?
11. When heat must be applied to a bearing ring, it should not exceed ________°F or ________°C.
12. Name two safety devices used when pulling bearings.
13. If a bearing is started in a "cocked" position, it will line up under pressure. True or False?
14. All pulling tools (striking type) should be of soft steel. True or False?
15. In that bearings are hardened, a little fine dirt will not hurt them. True or False?
16. It is permissible to mix bearing parts if they are in good shape. True or False?
17. Bearings are best cleaned in ______________ or ______________.
18. When blowing dry, never ____________ a bearing.
19. If you could only use one word to describe a proper bearing work area, that one word would be ____________.
20. List six common bearing defects.
21. A bearing showing some looseness should always be rejected. True or False?
22. Oil bearings before inspecting. True or False?
23. It is important, on a separable bearing, to inspect EVERY ball or roller. True or False?
24. When bearings will be stored for some time, they should be coated with ______________.
25. Always keep bearings ______________ until ready to use.
26. Immediately following inspection, bearings should be ______________.
27. Keep fingers away from bearing ______________ elements and ______________.
28. Before installing a bearing, inspect both ________ and __________ for nicks, burrs, and wear.
29. List 10 general rules regarding bearing installation and removal.
30. Write down the numbers of the bearings illustrated in Fig. 11-40. Opposite each number, write the letter of the correct name. Some of the following names are wrong!

A. Single row, deep groove ball.
B. Self-aligning thrust.
C. Single row, tapered roller.
D. Angular contact ball.
E. Self-aligning ball.
F. Self-aligning roller.
G. Spherical roller.
H. Double row, deep groove ball.
I. Ball thrust.
J. Straight roller.
K. Needle.

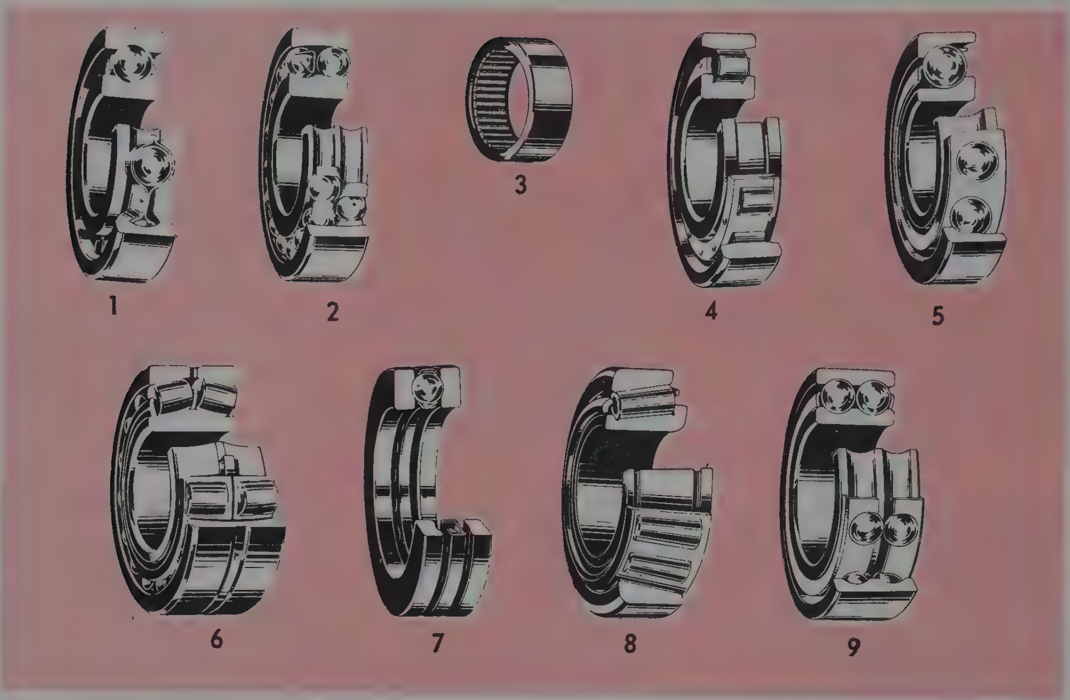
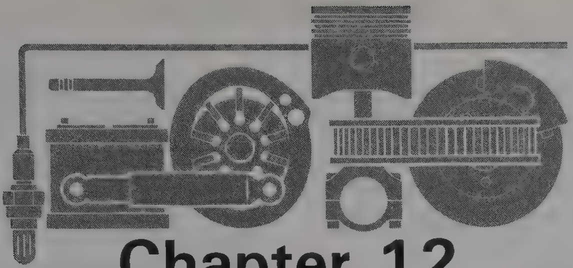


Fig. 11-40. Name these bearings. (SKF)



Chapter 12

ENGINE REMOVAL

After studying this chapter, you will be able to:

- ☐ Describe general procedures for removing an engine from a car.
- ☐ Explain the use of engine removal equipment.
- ☐ List safety rules that apply to engine removal.

GENERAL REMOVAL PROCEDURES

There are many ways that an engine can be removed from a car. Frame and body clearance, accessory equipment, and the possibility of removing transmission attached to engine must be considered for each job. Manufacturers' shop manuals will be helpful in determining specific steps for specific engines.

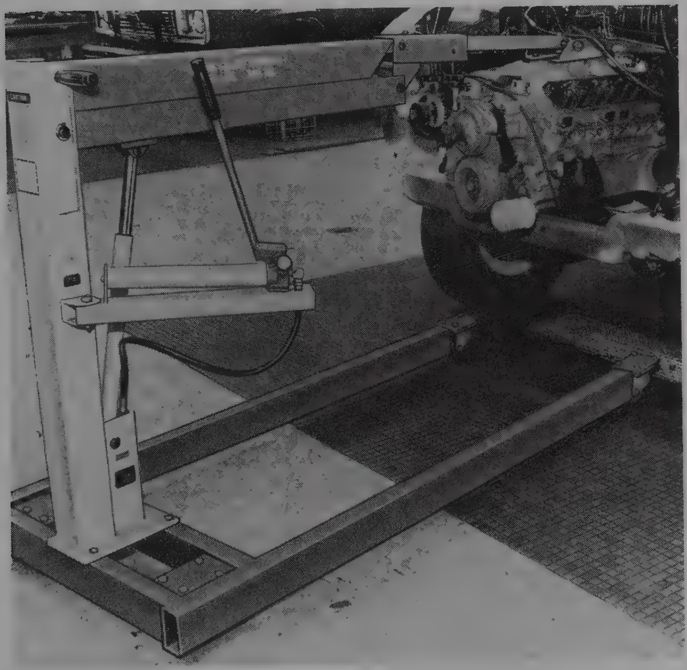


Fig. 12-1. Engine being removed out front of a van using a level lift floor crane. Note how crane is attached directly to intake manifold with a special adapter plate. (Owatonna Tool)

The vast majority of engines are pulled upward out of the engine compartment. A different procedure is required when the engine must be removed from the front. See Fig. 12-1.

Some installations allow the removal of the engine with the transmission attached. Others require it to be separated and the engine pulled by itself.

SUPPORT TRANSMISSION

If the engine alone is to be pulled, be certain to provide proper support for the transmission. The drive plate (provides drive from crankshaft to torque converter) will not support a load. If the transmission is not properly supported, serious damage can be done. An adjustable stand or a special frame cross member support may be used.

MAKE ROOM

Cover fenders with protective pads. If the hood hinge attaching point is adjustable, scribe around the hinge with a sharp pointed tool. The scribe lines will speed up hood alignment when replacing the hood. Look at Fig. 12-2.

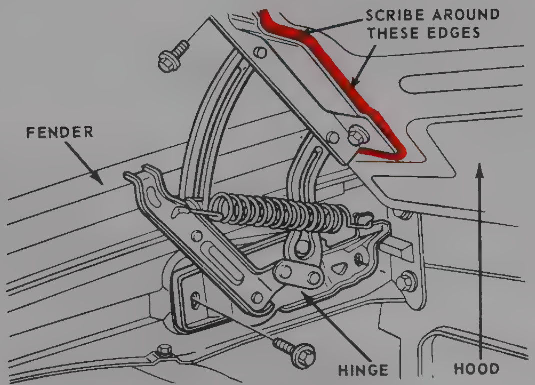


Fig. 12-2. Scribing around edges of hood hinge attaching plate will make hood alignment easy during reassembly. (Chevrolet)

Remove hinge fasteners. Lift off hood and store upright in a PROTECTED area. Place fasteners back so they will not be lost.

Drain the cooling system. Remove hose and radiator. Handle radiator carefully and protect during storage.

DISCONNECT ALL ATTACHED WIRING, TUBING, HOSES, AND CONTROLS

Remove the battery and battery cables. Disconnect coil primary lead, starter and alternator wires, oil pressure and temperature indicator wires, engine ground strap, and any other accessory wires. As the parts and wires are removed, they should be marked with masking tape for correct installation, Fig. 12-3.

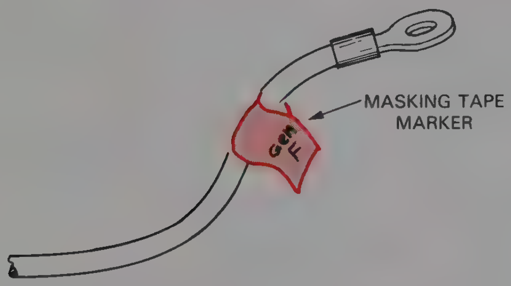


Fig. 12-3. Marking wires with tape will facilitate installation.

Disconnect the fuel and emissions lines, vacuum lines, oil pressure gauge line (if used), and any other line attached to the engine.

Remove the air cleaner and cover carburetor or throttle body with a plastic bag.

Disconnect carburetor or throttle body linkage and transmission T.V. (throttle valve) rod where used.

Disconnect exhaust pipe at exhaust manifold. Disconnect clutch linkage and transmission control rods (if transmission will be pulled with engine).

Disconnect speedometer cable at transmission. Drain engine and transmission. Remove oil filter. On vehicles with automatic transmission, remove fluid cooler lines. Plug lines to prevent entry of dirt. Disconnect propeller shaft or drive axles and wire out of the way.

Where used, remove transmission parking brake controls.

Remove the starter and alternator if necessary. The power steering pump, a/c compressor, etc., may be moved to one side or removed.

Check to make certain all necessary items have been removed.

AVOID PART DAMAGE

When pulling tubing and hose out of the way, be careful not to kink or damage them. Cover the ends of hose and tubing with tape to prevent the entry of dirt.

REPLACE FASTENERS

It is good practice, once a wire, control rod, or other part has been removed, to put the fasteners back into place. This will speed up reassembly and avoid improper placing of fasteners.

ATTACH LIFTING DEVICE

Attach the puller (crane) cable, strap, or bar to a suitable spot. Eyebolts may be used or head cap screws may be removed, placed through the puller brackets, and reinstalled. Some engines have specific attachment points. Consult manual.

Regardless of the attachment point, make certain that the eyebolt, cap screw, or bolt is threaded into the hole for a distance of at least one and one-half times its diameter. This will assure proper holding strength. See Fig. 12-4.

PULLER BRACKET MUST BE SNUG AGAINST ENGINE

Occasionally, the head or heads have been removed from the block. Never use the head cap screws or studs to attach the puller brackets unless they are shimmed to force the strap against the block. Failure to do this will place a heavy side pull on the fastener, causing it to fail. This same principle applies to any fastener that is too long, Fig. 12-5.

When attaching puller brackets, select fasteners of sufficient strength. Thread them into areas that will withstand the pressure of lifting.

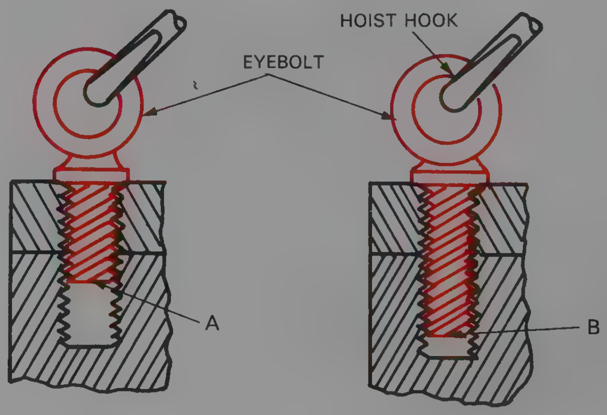


Fig. 12-4. Puller fastener must have ample thread. A—Eyebolt threads a very short distance into hole and will very likely rip out under pulling pressure. B—By using a longer eyebolt, ample thread is assured.

SELECT PROPER BALANCE POINT

Attach the puller so that the weight of the engine, or engine and transmission, will be balanced at the angle desired. Failure to do this will cause tipping that could spring parts and make removal difficult. Look at Fig. 12-6.

PULL POINT MUST NOT SLIP

Make certain that the pull point (point of attachment on puller) cannot slip under pressure. Fig. 12-7 shows what can happen when a chain hook is placed on a plain cable pulling strap.

Look at puller strap in Fig. 12-8. It allows the pull point to be moved along the length of the cable. However, under pressure, the hoist bracket will bind against the cable, thus preventing slippage.

POSITION LIFT

After the pulling device is firmly attached, move the lift into a position that will raise the engine without causing any undesirable side or fore and aft pressures. Insert the lift hook into the puller. Place a light lifting strain on the engine. Remove the engine mount bolts.

LIFT ENGINE

Start raising the engine while checking for proper clearance. Be careful of the lifting angle. If the engine

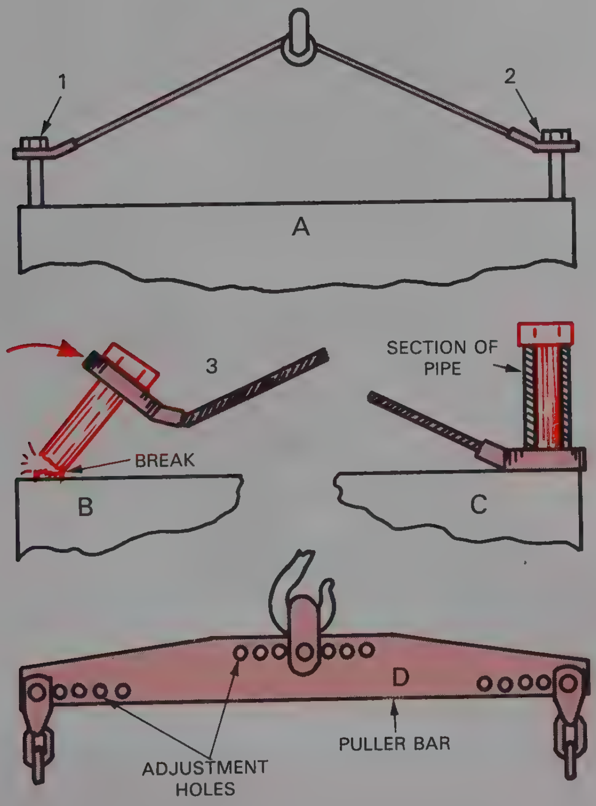


Fig. 12-5. A—Puller brackets (1) and (2) have slid up cap screws. B—When hoist exerts force on puller cable, puller bracket (3) will force cap screw sideways causing it to break or bend. C—Bracket is held against block by a short section of pipe to prevent cap screw damage. D—Typical puller bar. Note adjustment holes.

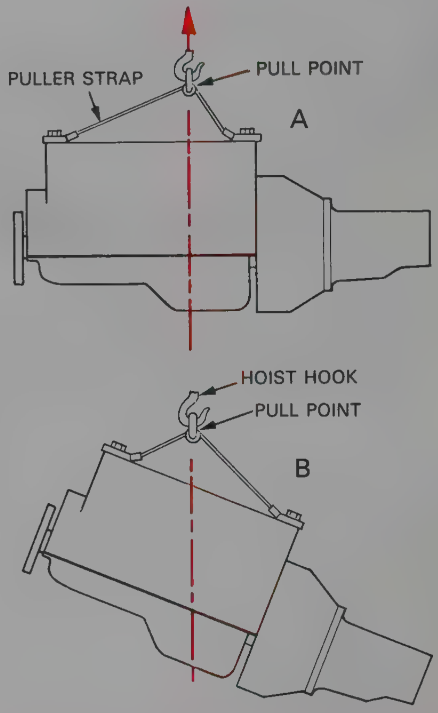


Fig. 12-6. A—Engine can be lifted in a level position by arranging pull point properly. B—Lifting angle is altered by moving pull point towards front of engine. Any number of angles are possible.

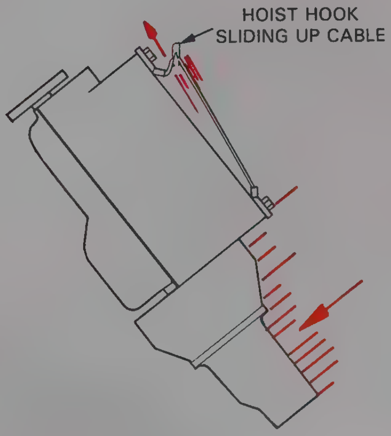


Fig. 12-7. Engine was being lifted by placing hoist hook around a plain cable puller strap. Rear of the engine tipped down and hoist hook slid to front end of cable. The rear of engine is now falling downward with dangerous force. MAKE CERTAIN PULL POINT CANNOT SLIP.

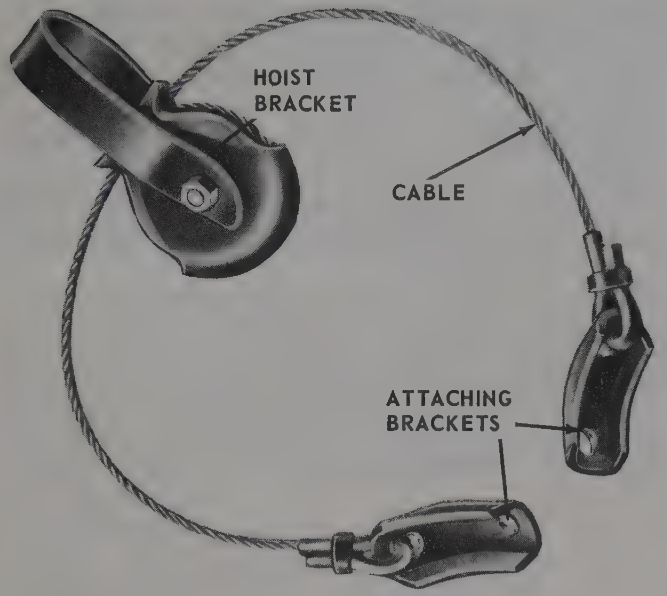


Fig. 12-8. Cable type engine pulling strap. Hoist bracket attaching point is adjustable but will bind under lifting pressure to prevent pull point change. (Snap-On Tools)

assumes the wrong balance angle, lower back into position and change either the pull point on the puller or the location of the puller brackets.

As the engine begins to rise, pull it forward until free of the transmission (when transmission will be left in place). As lifting progresses, be careful that the drive plate (automatic transmission) does not hang up.

If removing transmission with engine, the unit will often have to assume a relatively steep angle, such as that shown in Figs. 12-9 and 12-11 to clear.

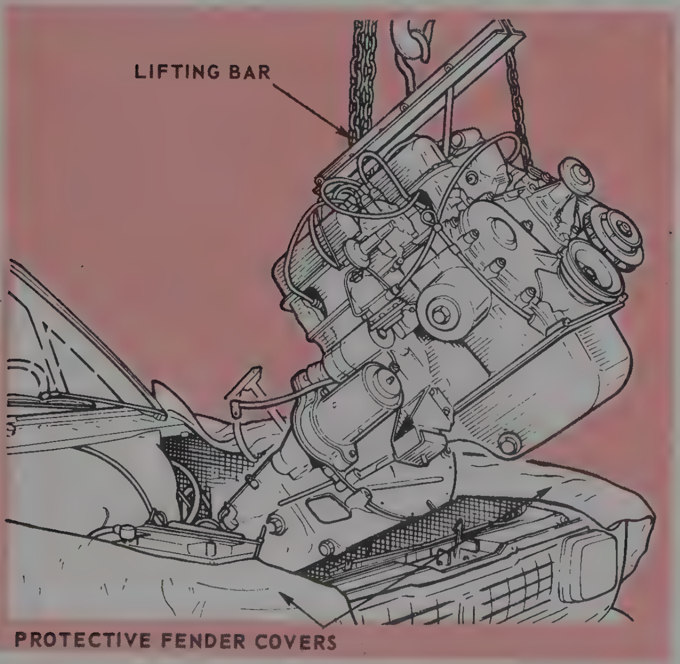


Fig. 12-9. Pulling an engine with a chain hoist. Note steep lifting angle necessary to provide clearance.

As the pulling continues, give the engine an occasional gentle rocking motion. This will ascertain that it is free. If the engine stops moving at one point and continues at another, stop and check for an obstruction. Continue raising while guiding the engine with the hands and by altering lift position.

Raise to a height sufficient to clear the car. Remove engine and immediately lower until just above the floor. Move to the cleaning area and steam clean. Remove transmission (if attached) and place engine in a suitable repair stand. See Fig. 12-10.

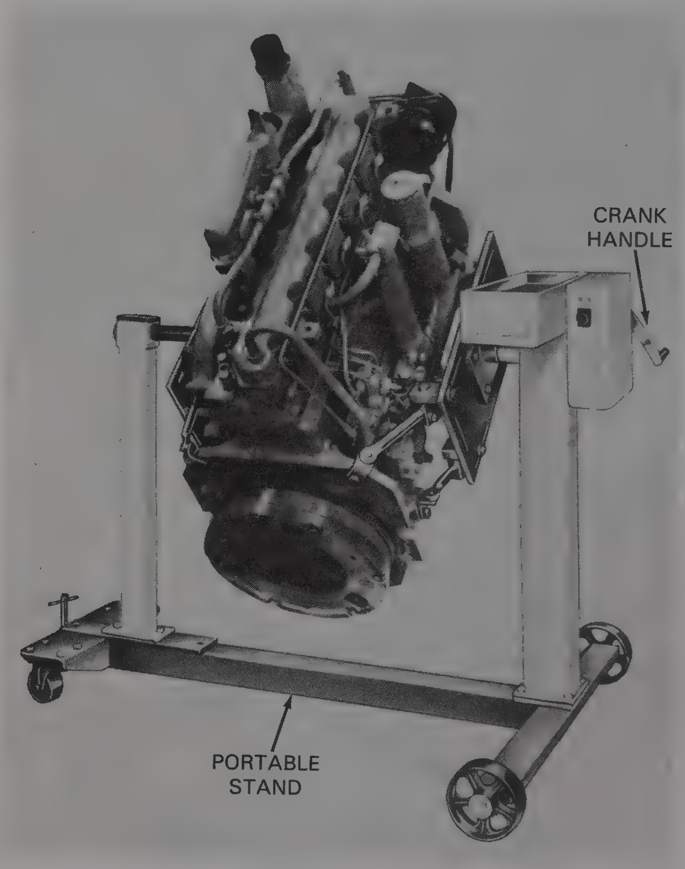


Fig. 12-10. After engine has been removed, it is placed in a stand. This aids in disassembly and reassembly. Note crank handle. When turned, engine will rotate. This provides easy access to various parts. (Owatonna Tool)

SAFETY RULES FOR PULLING

1. Attach lift strap or bar at correct balance point.
2. Lift strap fasteners must have ample thread and strap brackets should be in contact with engine - not on the end of a long cap screw or stud.
3. Watch hands and keep clear of engine at all times.
4. Lower as soon as engine is removed.
5. Do not use a rope as an engine sling.

6. Do not depend on a knot in a chain. Bolt it together.
7. If a chain is used as a strap, use heavy, wide washers under the head of the fastener to prevent the fastener head from pulling through the link.
8. Make sure the pulling point cannot slip.

SUMMARY

Determine if transmission will be pulled with engine. Cover fenders. Scribe hinges and remove hood.

Drain water, remove hose and radiator. If desired, drain engine and transmission.

Disconnect all wiring, tubing, hose, and controls attached to engine and, if necessary, to transmission.

Attach puller strap securely to properly balance the assembly.

Pull engine slowly, checking to make certain all parts are free. When high enough to clear, remove and lower. Steam clean and place in a repair stand.

Be very careful. Stay out from under the engine at all times.

KNOW THESE TERMS

Fender cover, Puller cable, Eyebolt, Balance point, Pull point, Puller bar, Lifting angle, Chain hoist, Hydraulic extension jack, Transmission support, Puller strap.

QUIZ - Chapter 12

1. Engines must always be pulled with:
   a. Transmission attached.
   b. Transmission removed.
   c. Varies - sometimes attached and sometimes removed.
2. If adjustable, ____________ around hood hinges before removal.
3. Whenever practical, always __________ fasteners after a part is removed.
4. ____________ wire ends after removal to facilitate reassembly.
5. Engine angle during lifting should be:
   a. Level.
   b. Back tipped down.
   c. Front tipped down.
   d. Depends on job at hand.
6. As soon as the engine assembly will clear the car, remove engine and lower.
7. A gentle rocking motion will help to determine if engine is clear during pulling.
8. Lift strap or bar brackets should be attached to:
   a. Head bolts.
   b. Intake manifold.
   c. Exhaust manifold.
   [✓ d.] Depends on situation.
9. When pulling tubing free of engine, be careful to avoid kinks or damage
10. List seven safety rules for engine pulling.

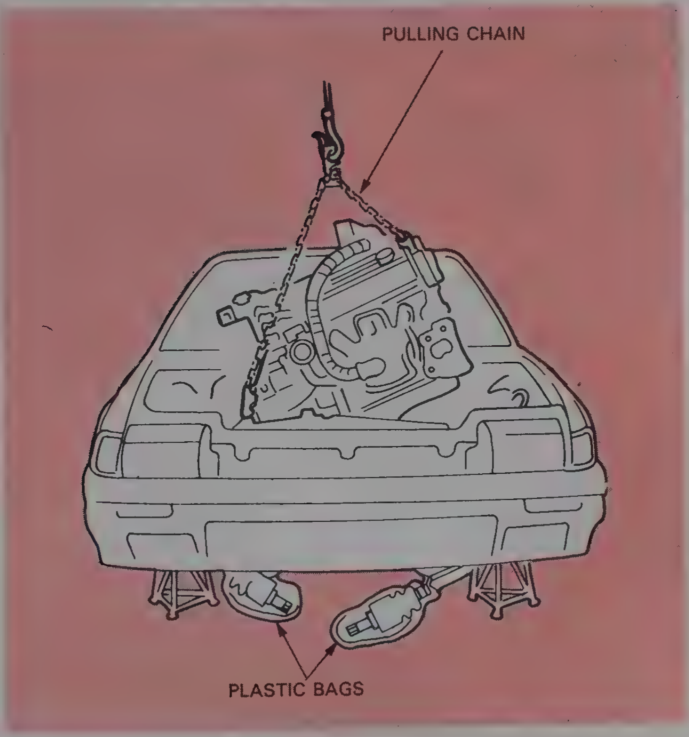
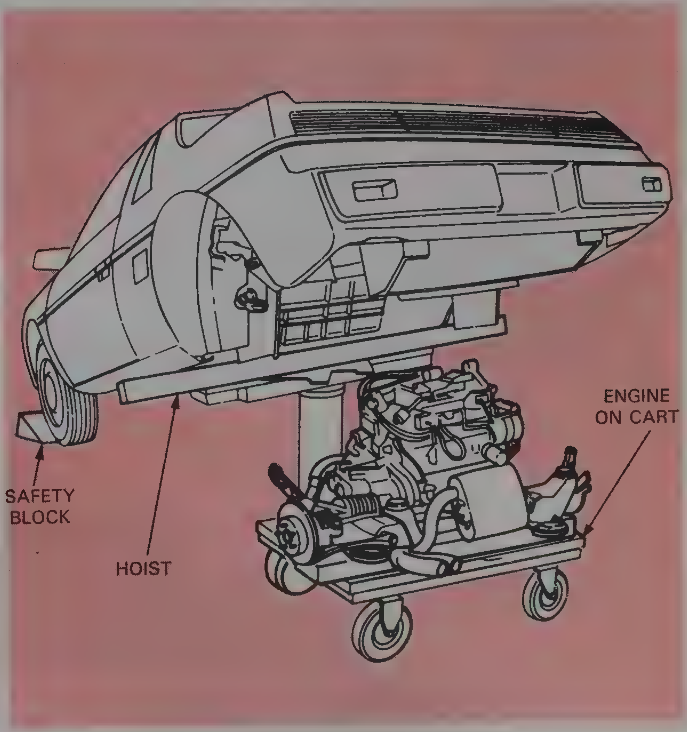
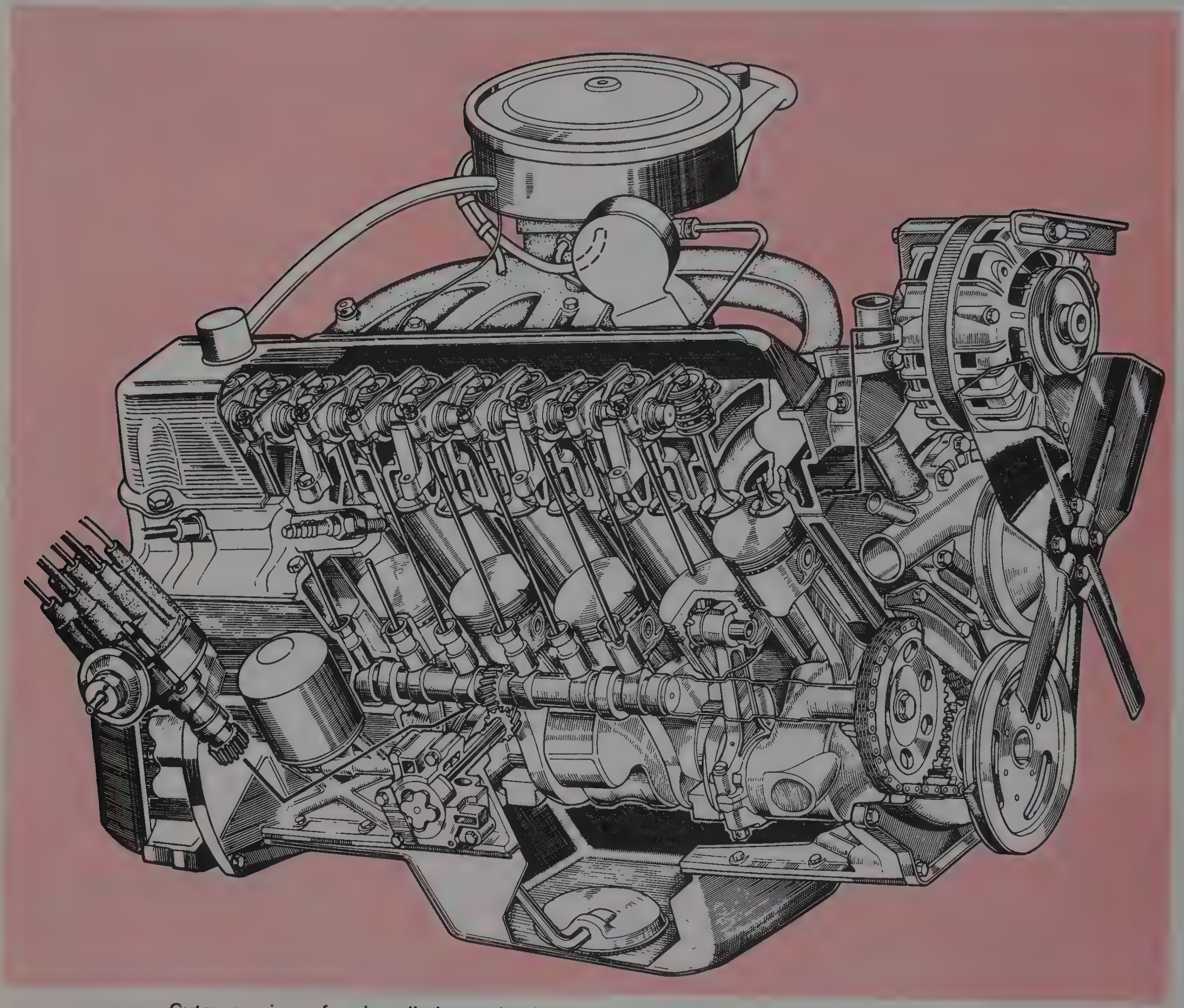


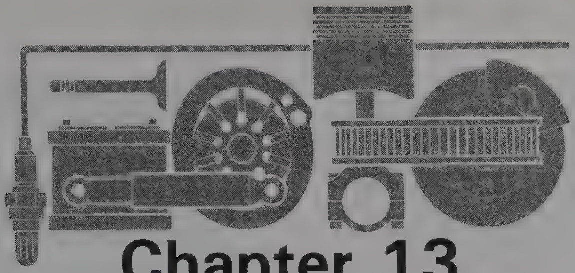
Fig. 12-11. Pulling an engine and transaxle. Note plastic bags over axle joints to keep dirt, water, etc., out. (Honda)



Removing an engine/transaxle from a mid-engine car. (Pontiac)



Cutaway view of a six cylinder engine in which block is slanted to one side. (Plymouth)



Chapter 13

CYLINDER HEAD, VALVE, AND VALVE TRAIN SERVICE

After studying this chapter, you will be able to:

☐ Properly remove and disassemble a cylinder head.
☐ Inspect the cylinder head and valve train for signs of trouble.
☐ Properly grind valve seats and valves.
☐ Test valve springs.
☐ Service valve guides.
☐ Reassemble and install a cylinder head.

CYLINDER HEAD REMOVAL

Never remove a cylinder head until the engine has cooled. Removal while hot can cause the head to warp upon cooling.

Remove intake and exhaust manifolds (when required), spark plugs, wires, rocker arm cover, and any accessory units attached to the head.

REMOVING ROCKER ARM ASSEMBLY

Remove the rocker arm assembly by starting at one end. Loosen each support bracket bolt, one after the other, a couple of turns. Repeat until the assembly is free. If each bracket bolt is completely removed before moving to the next, the last bracket could be damaged. Valve spring pressure could push the free portion of the shaft upward. See Fig. 13-1.

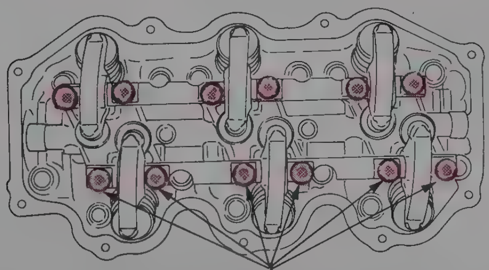


Fig. 13-1. Loosen rocker arm support bracket cap screws, one after the other, a little at a time. (Nissan)

On engines using ball stud type rocker arms, loosen each ball nut until the rocker arm can be swiveled sideways to clear the push rod. Look at Fig. 13-2.

In cases where rocker arm shaft support brackets are an integral part of the head, the head may be pulled before sliding the rocker shaft out of the brackets.

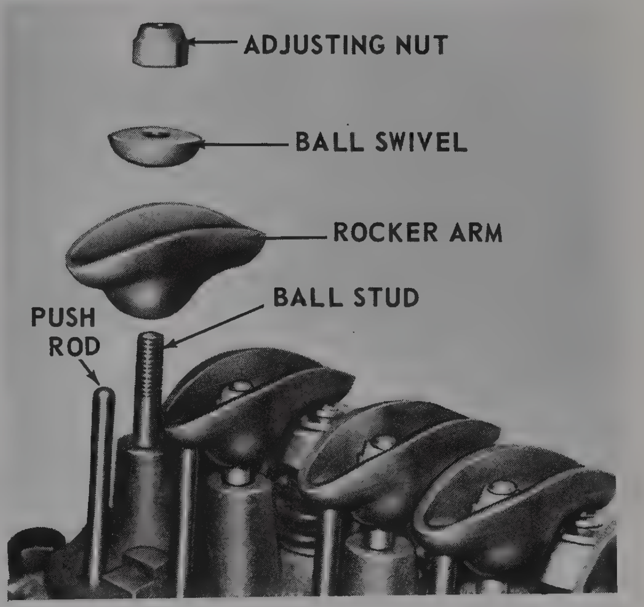


Fig. 13-2. Loosen adjusting nut enough to allow rocker arm to swivel sideways and clear push rod. (G.M.C.)

REMOVE PUSH RODS

Remove and place each push rod in a marked holder so it can be replaced in the original position. Use holder such as shown in Fig. 13-3.

LOOSEN CYLINDER HEAD FASTENERS

Using the recommended tightening sequence, reverse the order and crack (just break loose) each head cap

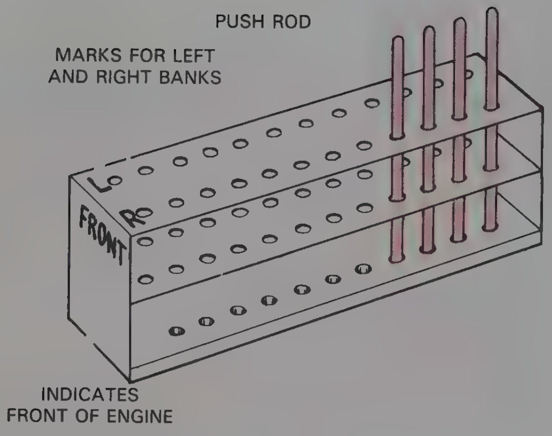

PUSH ROD
MARKS FOR LEFT AND RIGHT BANKS
L
R
FRONT
INDICATES FRONT OF ENGINE

Fig. 13-3. Place push rods in a marked holder - in proper order.

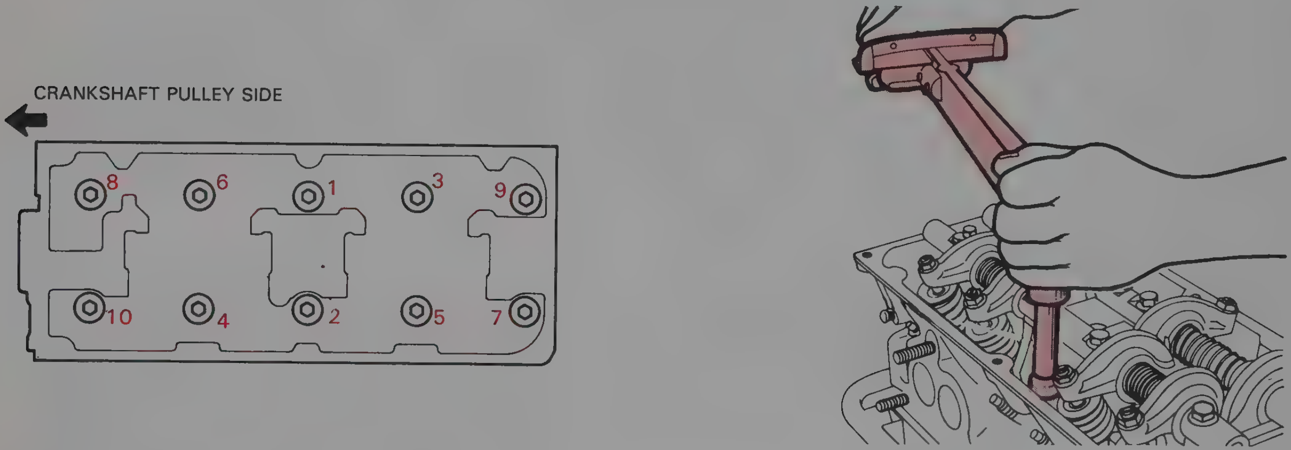

CRANKSHAFT PULLEY SIDE
8
6
1
3
9
10
4
2
5
7

Fig. 13-4. "Crack" cylinder head bolts. Remove in reverse order of tightening. (Chrysler)

screw. Once all have been loosened, they may be removed. If length varies or if a cap screw is drilled or machined for oil passage, note the correct location, Fig. 13-4.

If cylinder head is stuck, use pry bars or a lead hammer. Be careful not to damage the head. Avoid jamming any tapered object between head and block mating surfaces. The slightest nick or dent may cause serious damage. When the head is loose, remove it, as in Fig. 13-5.

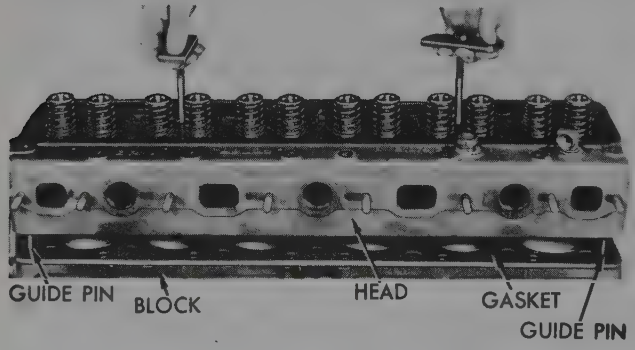

GUIDE PIN
BLOCK
HEAD
GASKET
GUIDE PIN

Fig. 13-5. Removing cylinder head. Note lift brackets. (G.M.C.)

PLACE CYLINDER HEAD IN HOLDING FIXTURE

Following removal, place the cylinder head in a suitable repair stand. Compress the valve springs, remove the split keepers, spring, and spring retainer assembly. Refer to Figs. 13-6 and 13-7.

KEEP VALVES IN ORDER

As they are removed, place valves in a rack so they may be replaced in their original guides. Use a rack similar to that shown in Fig. 13-3.

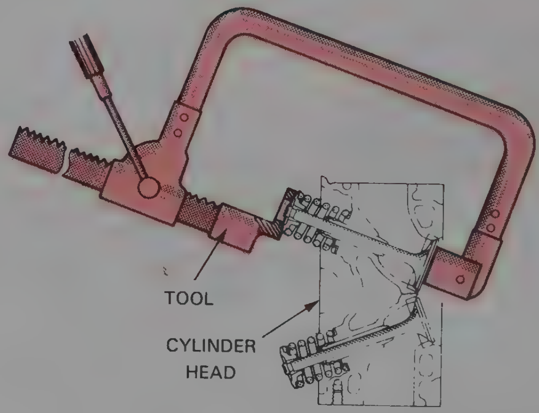

TOOL
CYLINDER HEAD

Fig. 13-6. Compressing valve springs with a valve spring compressor. (Chrysler)

VALVES TELL A STORY

Inspect each valve for signs of burning, pitting, and heavy carbon deposits. Burned or pitted valves can be caused by valves sticking in guides, insufficient tap-

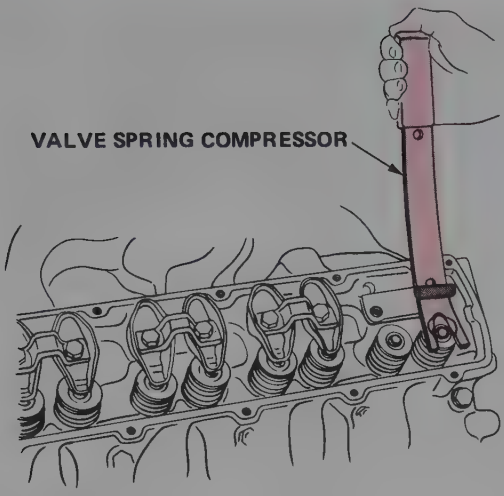


Fig. 13-7. Another form of valve spring compressor. This is particularly handy for removing a spring with head in place on engine.

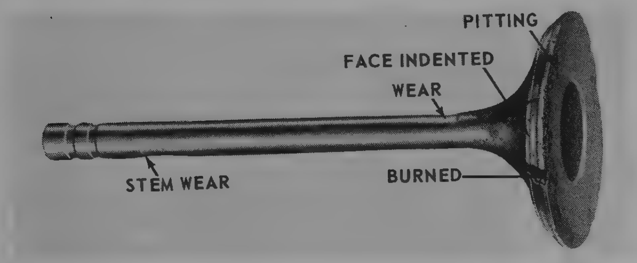


Fig. 13-8. A burned valve indicates problems. (Albertson-Sioux)

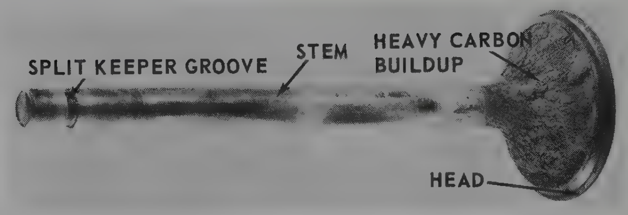


Fig. 13-9. Heavy carbon deposits under valve heads indicate excess oil consumption through valve guides. (Clevite)

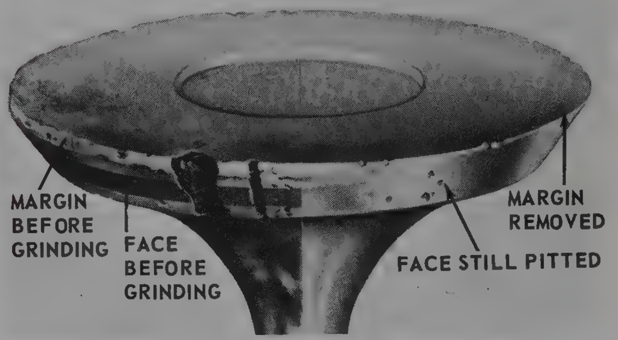


Fig. 13-10. The amount of grinding required to clean up a valve in this condition will remove margin and render valve useless.

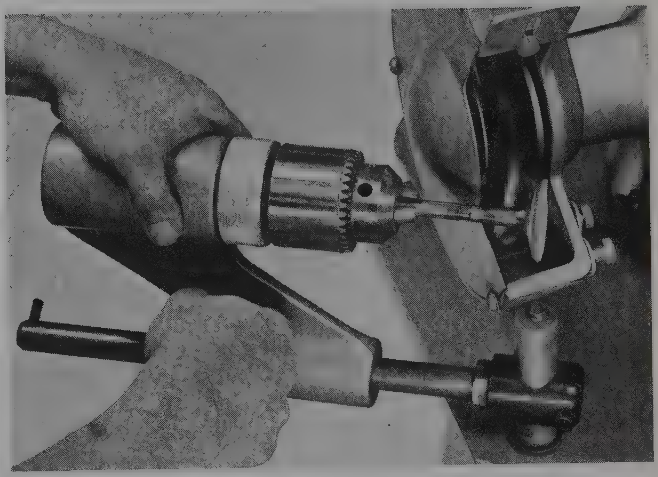


Fig. 13-11. Using a wire wheel to clean carbon from valve. Note use of special chuck which allows valve position to be changed while safely grasping valve stem. (Sioux Tools)

pet clearance, weak springs, clogged coolant passage, warped valve stem, and improper ignition or valve timing. See Fig. 13-8.

Heavy carbon deposits, especially under the head of the intake valve, indicates worn valve guides, damaged seals, worn rocker arm bushings allowing overlubrication, clogged oil drain holes in head, or rocker arm shaft oil holes facing the wrong direction. Look at Fig. 13-9.

Discard all badly burned, cracked, or warped valves. The grinding necessary to clean them up will leave insufficient valve margin, Fig. 13-10.

CLEAN VALVES THOROUGHLY

Using a power wire wheel, brush all traces of carbon from valve head and stem. Following wire brushing, rinse in solvent and blow dry, Fig. 13-11.

GRIND VALVES

Determine the correct valve face angle. On some engines, both intake and exhaust angles are the same. On others, they are different. Common angles are 30 and 45 deg.

To provide fast initial seating, it is often recommended practice to grind the 30 deg. valve to 29 deg. and the 45 to 44 deg. This provides an interference fit that produces a hair line contact between the valve face and the top of the valve seat. Some manufacturers feel that due to valve design and material, the valve when heated, will then form a perfect fit, Fig. 13-12.

VALVE GRINDER

A typical valve grinder is shown in Fig. 13-13. Study the names of the parts.

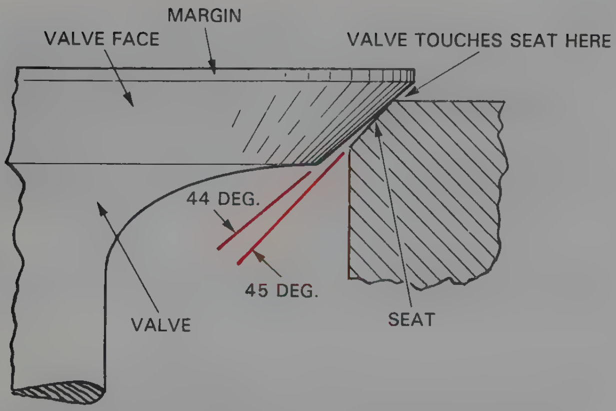

MARGIN
VALVE FACE
VALVE TOUCHES SEAT HERE
44 DEG.
45 DEG.
VALVE
SEAT

Fig. 13-12. Interference angle. Note ONE deg. difference in angles and how valve face contacts TOP edge of seat. One manufacturer recommends a TWO deg. difference on one specific engine.

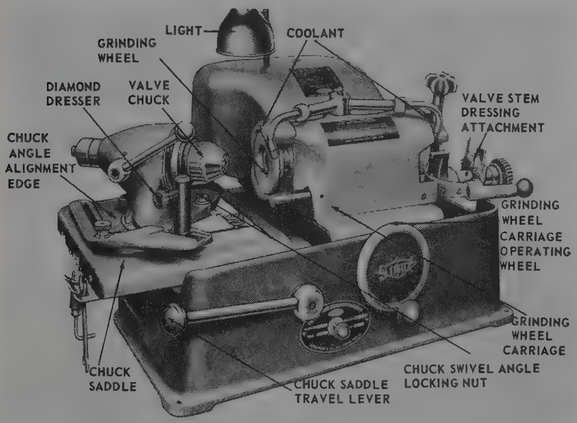

LIGHT
GRINDING WHEEL
COOLANT
DIAMOND DRESSER
VALVE CHUCK
CHUCK ANGLE ALIGNMENT EDGE
VALVE STEM DRESSING ATTACHMENT
GRINDING WHEEL CARRIAGE OPERATING WHEEL
GRINDING WHEEL CARRIAGE
CHUCK SWIVEL ANGLE LOCKING NUT
CHUCK SADDLE TRAVEL LEVER
CHUCK SADDLE

Fig. 13-13. A typical valve grinding machine.

DRESS STONES

A valve grinder will only perform a job in direct relation to the condition of the stones. THEY MUST BE DRESSED (trued up) TO THE CORRECT ANGLE AND KEPT IN THAT CONDITION. A good stone, properly dressed, will do better and faster work.

Put the diamond tipped dressing tool into position. Tighten securely. Start the machine and advance stone SLOWLY toward the diamond. When the diamond just touches, turn on the coolant. Move the diamond back and forth across the stone until the stone is smooth, clean, and true. Several VERY FINE cuts may be required. Move the diamond slowly, Fig. 13-14.

SET CHUCK ANGLE

Loosen chuck swivel nut and swing chuck to the proper angle. Adjust the chuck aligning edge to the selected angle marking very carefully. Lock swivel nut and recheck angle setting, Fig. 13-15.

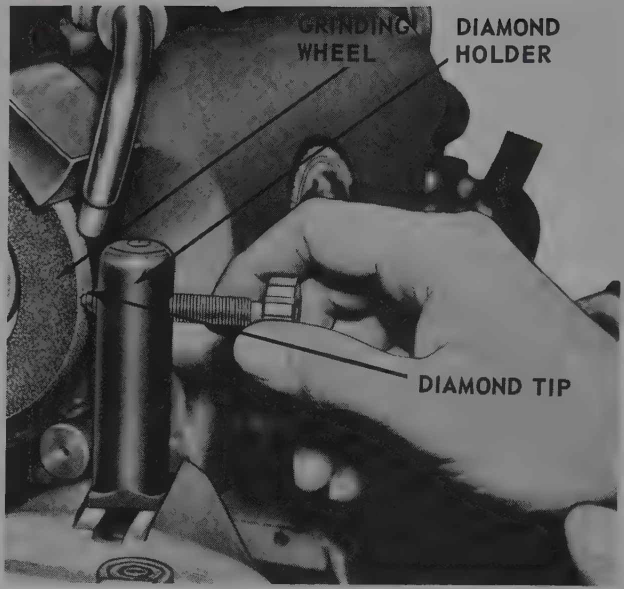

GRINDING WHEEL
DIAMOND HOLDER
DIAMOND TIP

Fig. 13-14. Dressing grinding wheel with a diamond dresser.

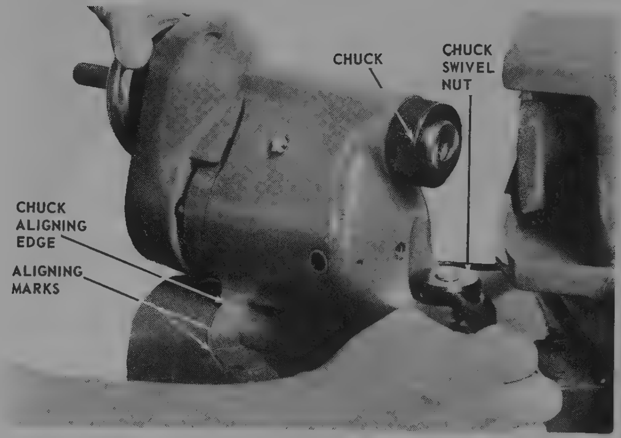

CHUCK
CHUCK SWIVEL NUT
CHUCK ALIGNING EDGE
ALIGNING MARKS

Fig. 13-15. Setting valve chuck to desired angle.

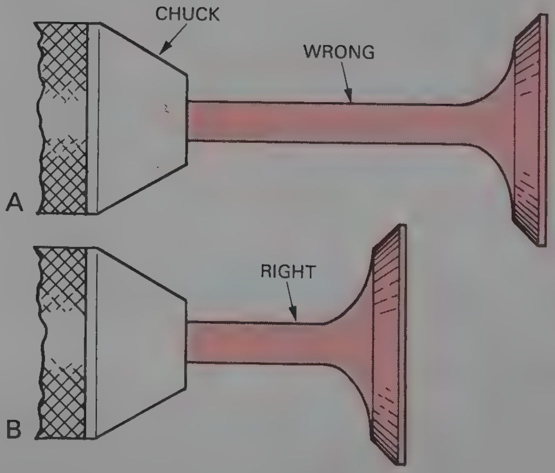

CHUCK
WRONG
A
RIGHT
B

Fig. 13-16. A—Valve protrudes too far out of chuck and will chatter. B—Valve depth is correct.

PLACE VALVE IN CHUCK

Place the valve in the chuck. Various gripping devices are used, so follow manufacturer's recommendations. Make sure the valve is in the chuck far enough so an excessive amount does not protrude and cause chatter (valve vibrating during grinding), Fig. 13-16.

Fig. 13-17 shows a valve being placed in the chuck. Close chuck tightly.

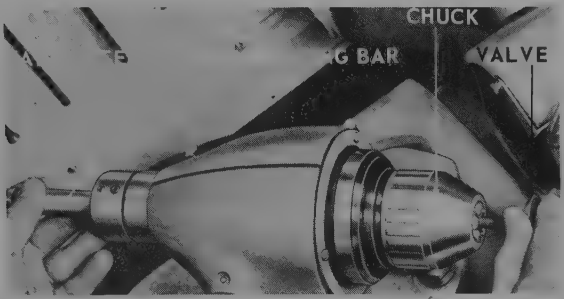


Fig. 13-17. Adjusting valve stem depth in the chuck.

CHECK FOR RUNOUT

Turn on the machine and watch the valve as it rotates. If a noticeable amount of runout (wobble) is present, stop the chuck. Loosen and reposition the valve. If excessive runout is still present, a warped stem is indicated. If warped to the point that grinding will leave insufficient margin, discard the valve, Fig. 13-18.

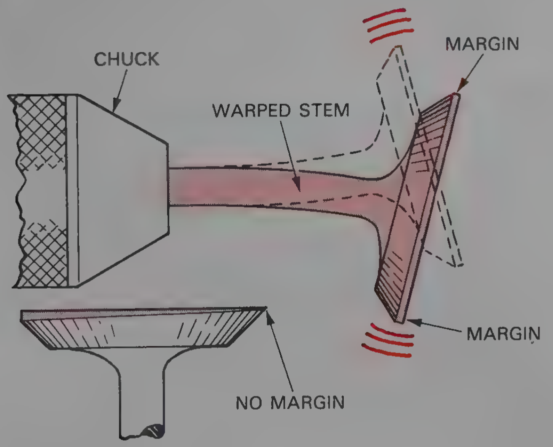


Fig. 13-18. Excessive valve "wobble" will cause valve margin to be removed on one edge.

GRIND VALVE FACE

Move the chuck saddle until the valve is in front of (not touching) the stone. Turn on the machine. Engage chuck drive to spin valve. Turn on the coolant and advance the wheel toward the valve. The valve face and stone should be parallel if you have selected the proper angle. See Fig. 13-19.

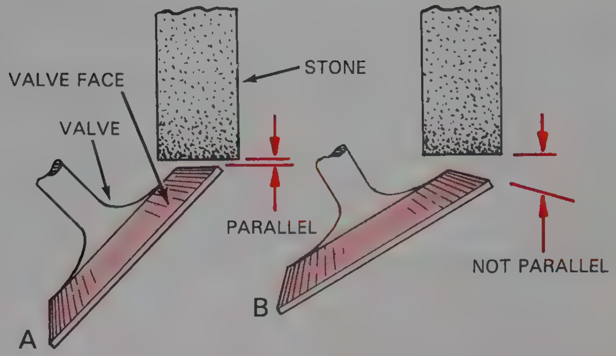


Fig. 13-19. If chuck is set at proper angle, valve face and stone will be parallel. A—Correct angle setting. B—Wrong angle adjustment.

If parallel, slowly advance the stone (make sure valve is turning) until it just starts to cut. Move the valve face back and forth across the stone. NEVER RUN THE VALVE OFF THE STONE, Fig. 13-20.

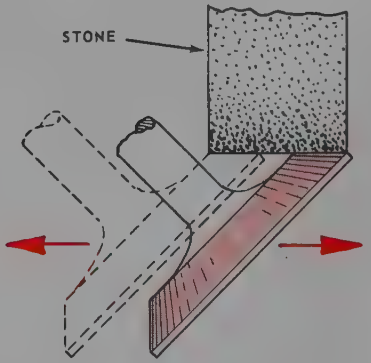


Fig. 13-20. When grinding, move valve back and forth keeping valve face in full contact with stone.

If your machine has a micrometer feed, set it to zero at the point where the stone just starts to cut. Advance the stone against the valve around .001 to .002 in. (0.025 to 0.05 mm) at a time. Watch the valve face. As soon as all dark spots disappear, center the valve face on the stone. Allow the stone to run a few seconds without advancing it. Then, carefully back the stone away from the valve.

Disengage the chuck drive and rotate the valve by hand while examining closely for any remaining pits or burns. The valve face should be bright, smooth, and free of ALL defects. The margin should be ample (1/32 in. or 0.03 mm or more). If the valve is not cleaned up, repeat the process. When finished, inspect the micrometer feed dial and mark down the amount of material removed from the valve. Return the valve to the holder.

Using the same procedure, grind the remaining valves. Do not forget to change angles if intake and exhaust are different.

WHEN FIRST USING A VALVE GRINDER, PROCEED SLOWLY. MANY BEGINNERS INADVERTENTLY TURN THE STONE FEED WHEEL THE WRONG WAY OR TOO FAST AND JAM IT AGAINST THE VALVE. IF THE CUT IS SUDDENLY TOO HEAVY, DO NOT PANIC AND CRANK THE WHEEL. YOU MAY TURN IT THE WRONG WAY. SHUT THE MACHINE OFF AND WHEN STOPPED, MOVE STONE AWAY.

The operator in Fig. 13-21 is grinding a valve face. Notice how the stone feed wheel is grasped. Even though it has a crank knob, once the stone is close to the valve, hold it as shown. This method will permit smoother and more accurate adjustments.

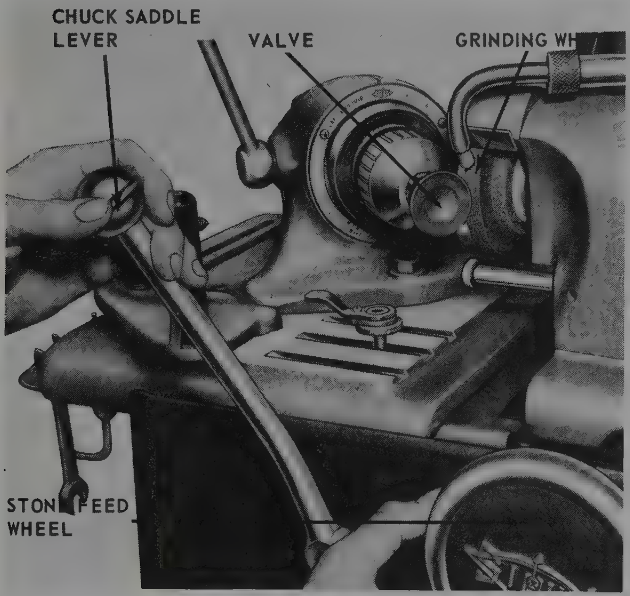


Fig. 13-21. Grinding valve face. (Albertson-Sioux)

GRIND VALVE STEM END

The valve stem end should always be trued up and smoothed by grinding. If you have marked down the amount removed from each valve face, it is recommended that you remove a comparable amount from the stem. This will help maintain original tappet clearance. However, never remove an excessive amount (up to about .010 in. or 0.25 mm) as the surface hardening is not too deep on some valves. If ground below the hardening, rapid wear will result.

Dress the side of the wheel used for stem grinding. Chuck the valve in the V-block holder. Run it in until it just touches the stone. If so equipped, set the micrometer feed dial to zero. Back off the valve. Start the wheel. Turn on the coolant and advance the stem against the wheel. Continue advancing with light cuts until the micrometer dial indicates that you have removed the same amount as was taken from the face. As with valve face grinding, direct a good stream of coolant on the portion of the valve being ground.

If the machine has no micrometer feed, remove enough to produce a smooth square end. Refer to Fig. 13-22.

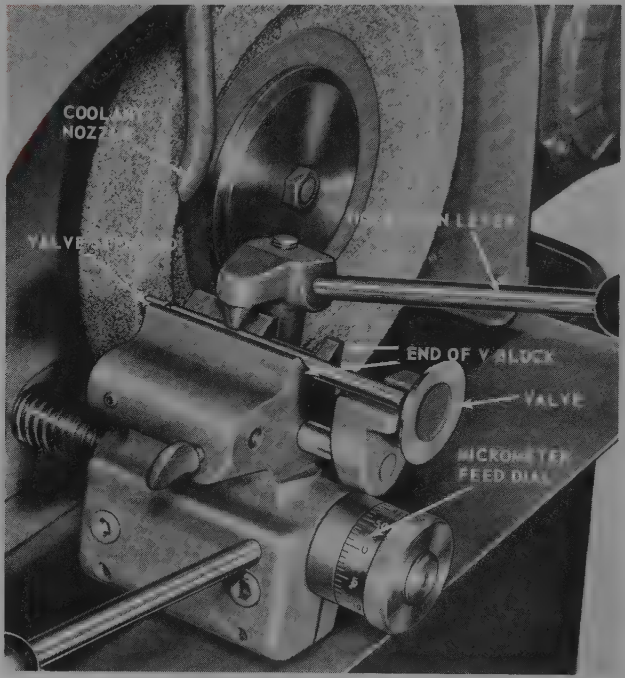


Fig. 13-22. Truing valve stem end. (Van Norman)

When using a plain V-block, in which the valve must be hand held, make certain the block is close to the wheel. This will prevent the valve stem from catching

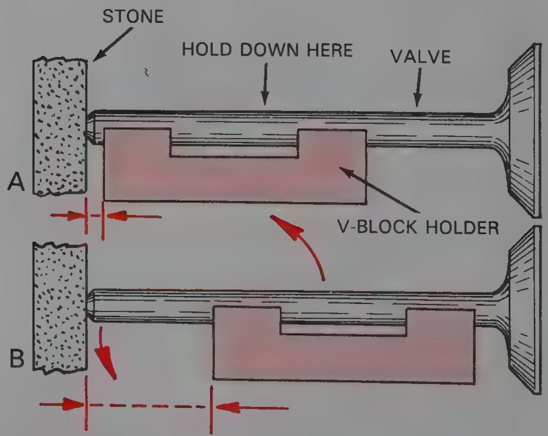


Fig. 13-23. A—Keep V-block close to grinding wheel. B—This setup is dangerous.

and pulling the valve between block and wheel. Position the valve stem in the block. Hold down firmly and advance stem against wheel, Fig. 13-23.

CHAMFER VALVE STEM END

If some of chamfer on the valve stem end has been removed through wear and refacing, the chamfer may be renewed by grinding. Place the valve in the V-block. Set the holder at 45 deg. and adjust stop to grind about a 1/32 in. (0.80 mm) chamfer, Figs. 13-24 and 13-25.

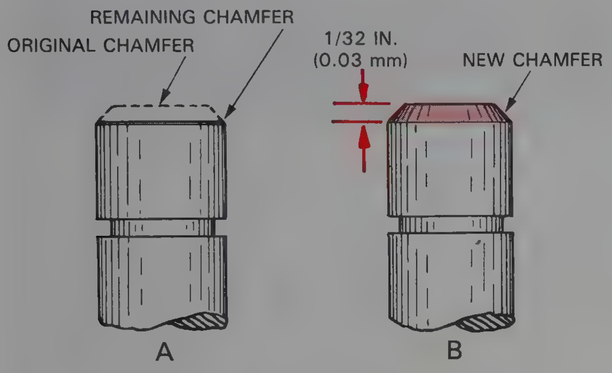

REMAINING CHAMFER
ORIGINAL CHAMFER
1/32 IN.
(0.03 mm)
NEW CHAMFER
A
B

Fig. 13-24. A—Valve stem end has chamfer worn off. B—Same after renewing chamfer.

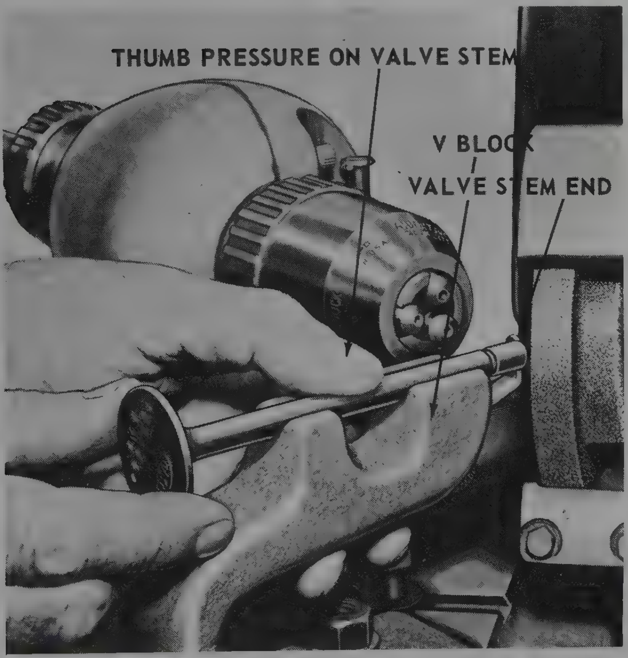

THUMB PRESSURE ON VALVE STEM
V BLOCK
VALVE STEM END

Fig. 13-25. Grinding a new chamfer on valve stem end.

EACH VALVE MUST PASS INSPECTION

Inspect each valve face. It must be smooth and free of all pits, scratches, and burns. There must be ample margin remaining to prevent burning. Valve stem wear must not be excessive. The stem should be free of nicks and scratches that could cause eventual breakage or sticking. Keeper grooves must be undamaged. Valve stem end must be smooth, squared, and lightly chamfered. CAUTION: SOME VALVES USE A SPECIAL COATING, SUCH AS NICKEL-CHROME, ON THE FACE AREA. ONLY A LIMITED AMOUNT CAN BE REMOVED! Check manufacturer's specifications. Fig. 13-26 illustrates two valves: one is acceptable, the other is not.

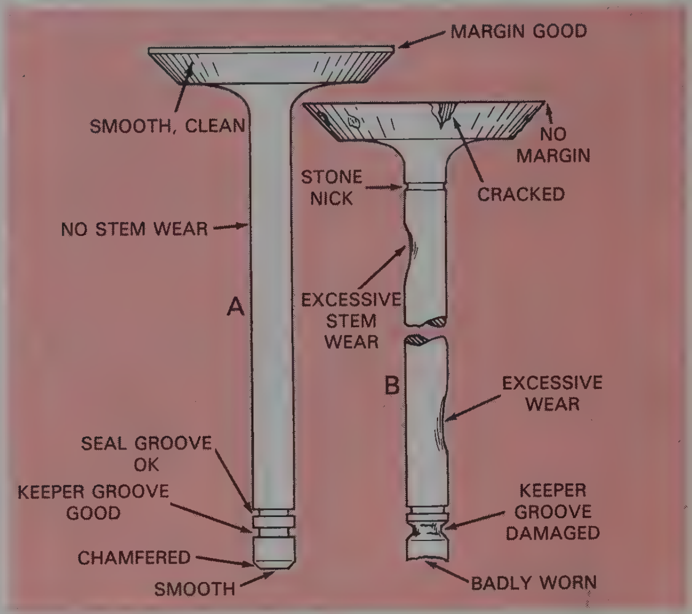

MARGIN GOOD
SMOOTH, CLEAN
NO MARGIN
STONE NICK
CRACKED
NO STEM WEAR
A
EXCESSIVE STEM WEAR
B
EXCESSIVE WEAR
SEAL GROOVE OK
KEEPER GROOVE GOOD
KEEPER GROOVE DAMAGED
CHAMFERED
SMOOTH
BADLY WORN

Fig. 13-26. A—Valve is acceptable. B—Valve is not acceptable.

WASH AND STORE

Following the final inspection, each valve must be thoroughly washed (check keeper grooves carefully) and blown dry. Place in a clean rack and cover until ready to use.

CLEAN CYLINDER HEAD

If the cylinder head coolant passages are badly clogged, give the head an initial cleaning in a "hot tank." Remove all carbon from the combustion chambers and valve ports. Wire brushes in a hand drill will do nicely. Clean the head to block surface with a scraper. Be careful not to put scratches in the surface, Fig. 13-27.

Run a spring-type valve guide cleaner up and down through each guide to remove the carbon. Look at Fig. 13-28.

Follow the valve guide cleaner with a valve guide bristle brush to remove all loosened carbon, Fig. 13-29.

Blow all dust and carbon from the combustion chambers, ports, and guides. Push a cloth, moistened with

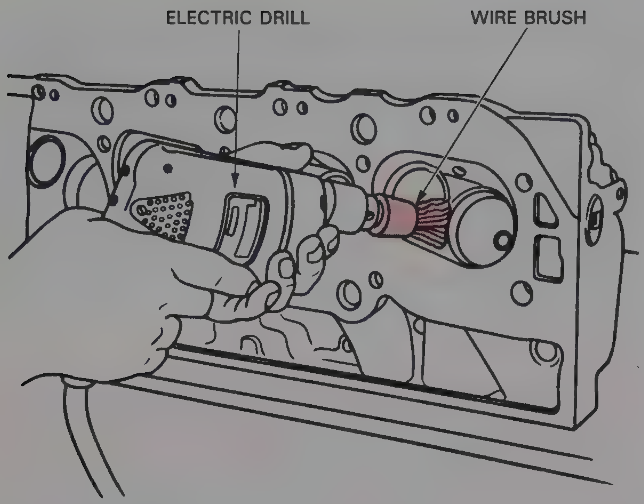

ELECTRIC DRILL
WIRE BRUSH

Fig. 13-27. Removing carbon from cylinder head combustion chamber and ports. Wear safety goggles! (Chevrolet)

solvent, through all the valve guides to make certain NO foreign material remains. This is very important because if some is left in the guide, the stem clearance check will not be accurate. When the seat grinding pilot is inserted, it will be tipped and throw the valve seat out of alignment.

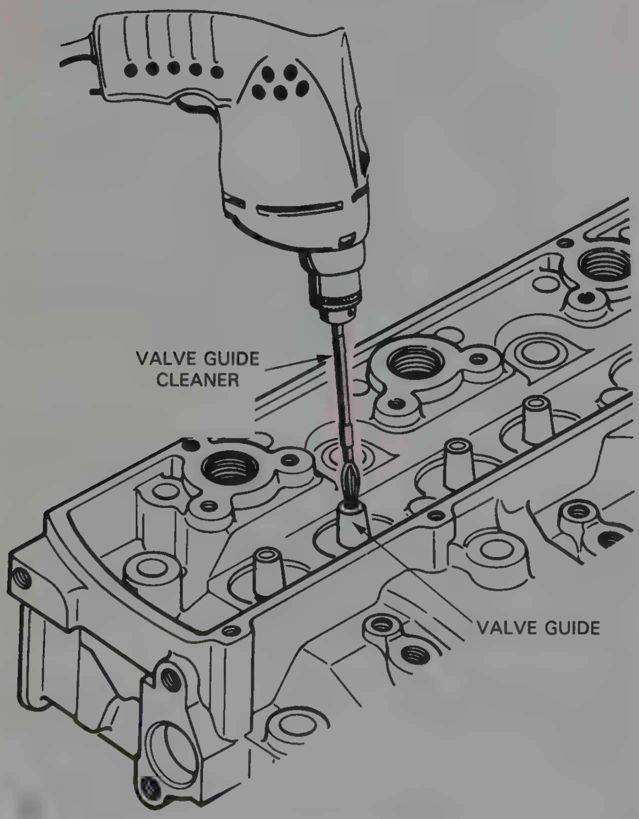

VALVE GUIDE CLEANER
VALVE GUIDE

Fig. 13-28. Using a spring blade valve guide cleaner to remove carbon from a valve guide. (Buick)

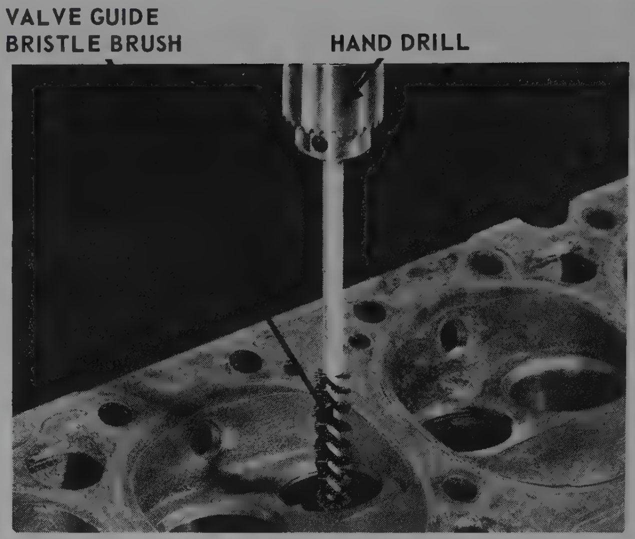

VALVE GUIDE BRISTLE BRUSH
HAND DRILL

Fig. 13-29. Removing loosened carbon from a valve guide. (Black and Decker)

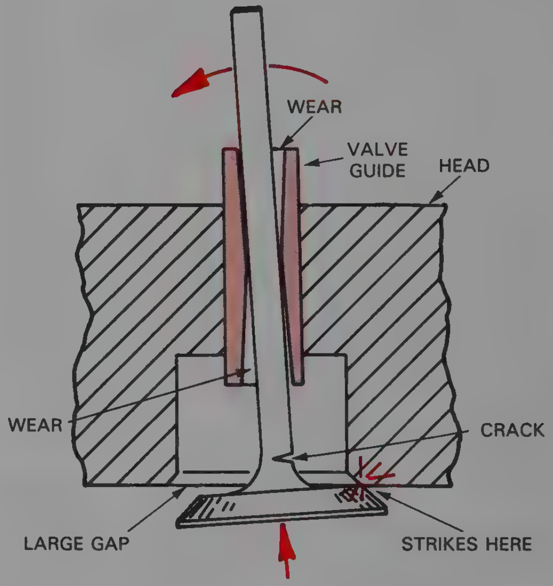

WEAR
VALVE GUIDE
HEAD
WEAR
CRACK
LARGE GAP
STRIKES HERE

Fig. 13-30. Excessive valve guide wear will cause trouble.

CHECK VALVE STEM TO GUIDE CLEARANCE

When deciding whether or not to use the old valve guides, you are not concerned about too little clearance (unless new oversize stem valves are being installed). Excessive clearance will often be present. This will promote oil consumption, poor seating, and possible valve breakage, Fig. 13-30.

Two methods are commonly used to check for excessive stem clearance. A small hole gauge (some valve seat grinder pilots can be used too) is carefully fitted to the largest valve guide diameter (do not measure exhaust guide counterbores). It is then removed and measured with an outside micrometer. The valve stem

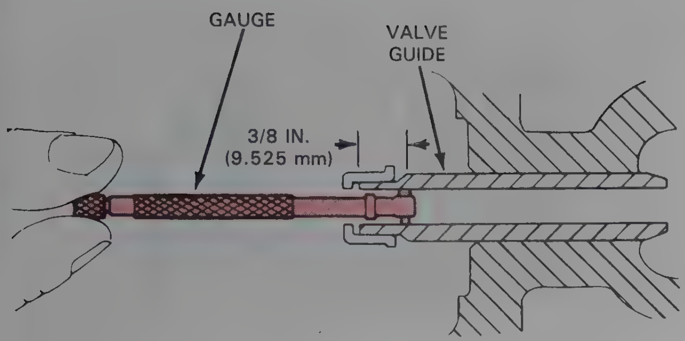


Fig. 13-31. Measuring valve guide inside diameter using a small hole gauge. Note depth at which measurement is obtained. (Jeep)

is then miked at a corresponding wear area. The difference can be computed to determine stem clearance, Fig. 13-31.

Another method is to drop the valve into position with the head just free of the seat. It can be held in this position by a special tool or by slipping a piece of rubber tubing of the correct length over the valve stem, Fig. 13-32.

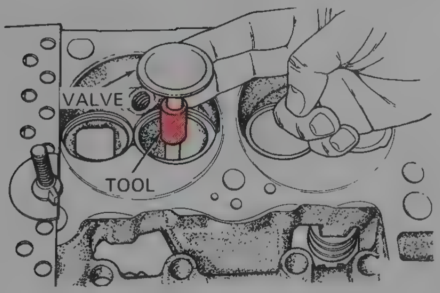


Fig. 13-32. Positioning valve with tool prior to checking stem-to-guide clearance with a dial indicator. (Dodge)

A dial indicator is then clamped to the head. The indicator stem is placed against the valve margin. Without raising the valve, move it back and forth against the stem. Watch the indicator to determine the travel.

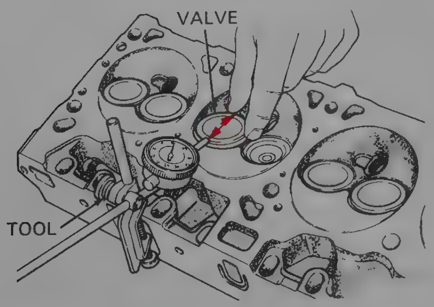


Fig. 13-33. Checking valve stem play to determine stem-to-guide clearance.

Remember that the reading will not be the actual clearance because the measuring point is above the guide. The tipping effect will magnify the reading. Follow the manufacturer's recommendations for maximum allowable movement, Fig. 13-33.

EXCESSIVE CLEARANCE

Engine design, type of oil seal, and amount of lubrication all determine acceptable clearance. Follow manufacturer's specifications. Generally, when the actual valve stem clearance exceeds .005 to .006 in. (0.13 to 0.15 mm), it is considered excessive.

Remember that both the guide and stem wear less in the center. Even though a stem-to-guide clearance at the center is correct, the clearance at the ends may be excessive and cause tipping, Fig. 13-34.

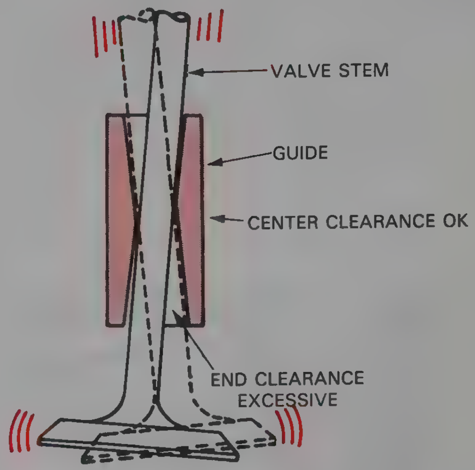


Fig. 13-34. Stem-to-guide clearance near end of guide must be within limits. Note that correct clearance in guide center will not prevent tipping.

When an excessive stem-to-guide clearance is present, the valve guides (if removable) may be replaced. When the guides are integral (part of head), they may be reamed to oversize, and new valves with oversize stems installed. See Fig. 13-35.

CAUTION!

Some exhaust valve stems are partially filled with metallic sodium which aids in valve cooling. When the valve is worn out, dispose of it properly. NEVER cut, drill, melt, or burn. Always follow manufacturer's recommendations for proper disposal.

REPLACING VALVE GUIDES

The guides may either be driven or pressed out. The punch should have a pilot section extending into the

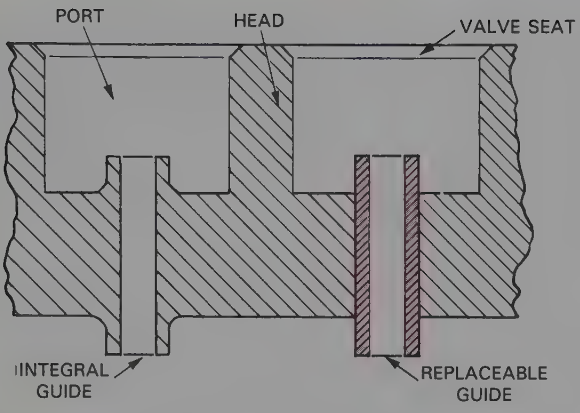

PORT
HEAD
VALVE SEAT
INTEGRAL GUIDE
REPLACEABLE GUIDE

Fig. 13-35. Integral and replaceable valve guides.

guide. The pilot should be a few thousandths smaller than the guide hole to prevent binding. This is due to guide hole diameter reduction when using the punch for installation.

The main body of the punch should be slightly smaller than the guide so it will follow the guide through the hole. Contact edge should be smooth and square with punch centerline.

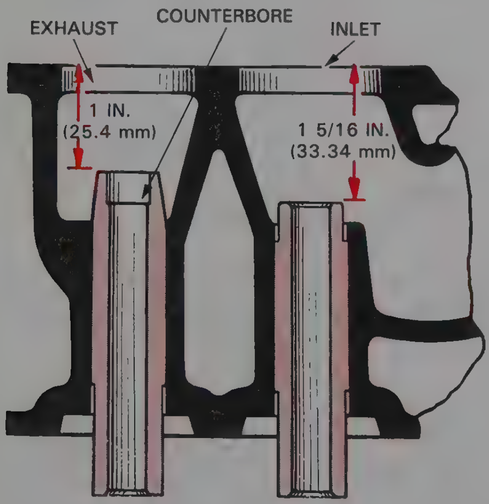

EXHAUST
COUNTERBORE
INLET
1 IN.
(25.4 mm)
1 5/16 IN.
(33.34 mm)

Fig. 13-36. Guide depth in this case is measured from the surface on the valve seat side. Note the shape of the ends facing the seats. (AMC Jeep)

Before driving out the guides, make a note of the distance from the surface of the head to the face of the guide as well as the shape of the end that extends into the combustion chamber. Identify exhaust from intake shapes. By doing this, it will be possible to get the correct guide for each hole, proper end up, and driven into the correct depth. Look at Figs. 13-36 and 13-37.

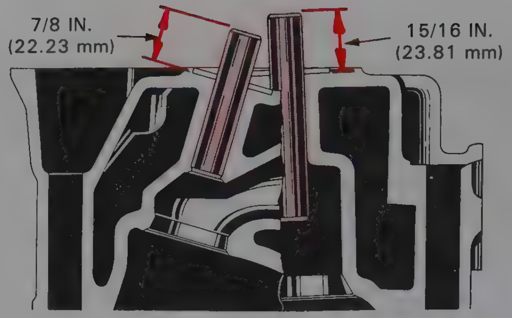

7/8 IN.
(22.23 mm)
15/16 IN.
(23.81 mm)

Fig. 13-37. Guide depth, in this engine, is measured from the valve spring seat surface. (Chevrolet)

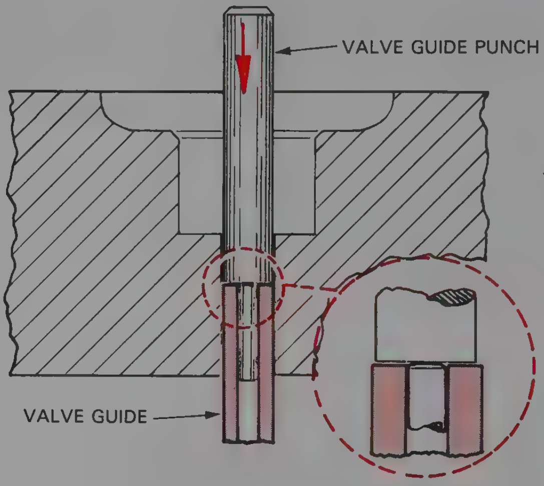

VALVE GUIDE PUNCH
VALVE GUIDE

Fig. 13-38. One form of valve guide punch.

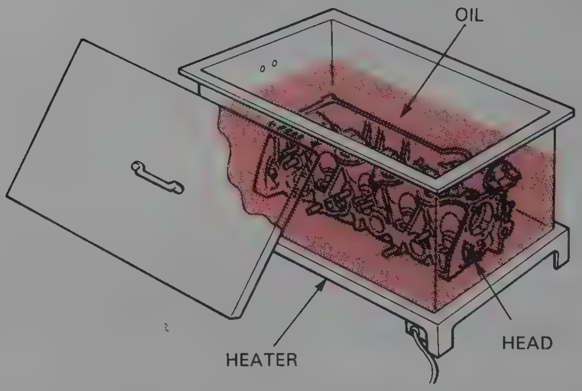

OIL
HEAD
HEATER

Fig. 13-39. Head is heated in oil to about 302 °F to assist in removing valve guides. (Nissan)

Place the punch in the guide. While holding the punch in firm contact (guides are brittle and may crack if punch is loosely held), drive the guide from the hole. Refer to Fig. 13-38. Some designs require heating head in oil before removing guides, Fig. 13-39.

INSTALLING GUIDES

The guide holes must be SPOTLESSLY CLEAN. If a refrigerator or freezer is handy, the guides may be placed in the freeze box long enough to thoroughly chill them. Dry ice or liquid nitrogen may also be used. The resultant reduction in diameter will aid in their installation.

Give the guide and hole a thin coat of hypoid lubricant (Lubriplate or similar type). Insert the proper end in the correct guide hole. Drive it to the specified depth. DO NOT DRIVE PAST THE REQUIRED DEPTH. A stop on the tool may be used. As in Fig. 13-40, a punch mark may also be used to provide a means of measuring from a given surface.

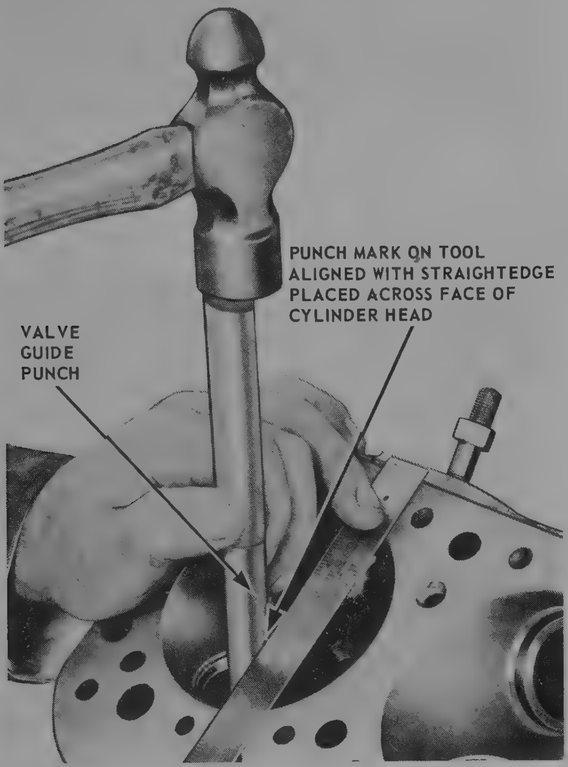

VALVE GUIDE PUNCH
PUNCH MARK ON TOOL ALIGNED WITH STRAIGHTEDGE PLACED ACROSS FACE OF CYLINDER HEAD

Fig. 13-40. Using a punch mark on tool to determine when guide has been driven to the proper depth. (Kelsey-Hayes)

REAMING GUIDES AFTER INSTALLATION

Some guides are factory reamed and following installation, require no reaming. If the guides must be reamed, use a special valve guide reamer of the exact size. Start the reamer carefully and turn it clockwise both while entering and leaving the guide. Ream dry. Be careful to avoid any side pressure on the reamer. Allow the pilot portion to guide it through. A properly reamed guide will provide around .002 in. (0.05 mm) guide clearance (see manufacturer's specs), Fig. 13-41.

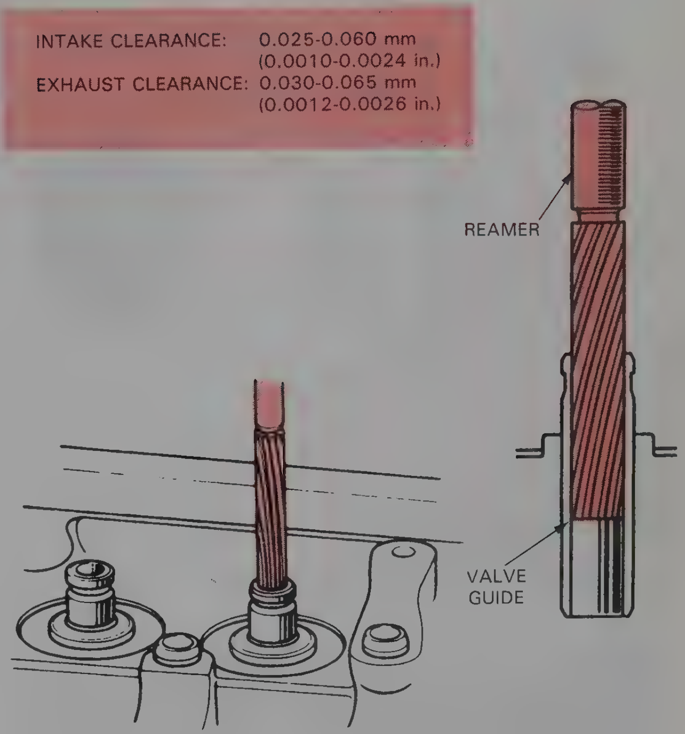

INTAKE CLEARANCE: 0.025-0.060 mm (0.0010-0.0024 in.)
EXHAUST CLEARANCE: 0.030-0.065 mm (0.0012-0.0026 in.)

Fig. 13-41. Reaming a valve guide bushing. Note the close tolerances between valve guide and valve stem. (Chevrolet)

WORN INTEGRAL GUIDES

When the guide is cast as part of the head, it is necessary to determine the extent of the wear. If excessive, a new valve with a suitable oversize stem is selected. The worn guide is then reamed to fit the valve stem. Stem oversizes generally are available in .003, .015, and .030 in. (0.08, 0.38, and 0.76 mm). As with removable guides, use a SHARP reamer of the CORRECT size. Following reaming, wash guides and blow dry.

PREPARING VALVE GUIDE FOR OIL SEAL

Some guides are designed to accept special oil seals; others are not. Fig. 13-42 shows one type of guide seal. The guide illustrated is already machined to fit the Teflon seal.

Both integral and removable guides may be prepared for this seal. Fig. 13-43 illustrates a special cutter machining an integral guide in preparation for seal installation.

To install this particular seal, the valve stem end is covered with a protective plastic cap. The seal is then pressed over the end and down the stem, Fig. 13-44.

The seal is forced over the machined section of the guide as far as possible with the fingers. To complete the seating, a special tool is used to grasp the seal and force it fully down, Fig. 13-45.

BOTH INTAKE AND EXHAUST GUIDES ADMIT OIL TO COMBUSTION CHAMBER

Although oil is somewhat more likely to pass through the intake guide due to the strong vacuum in the

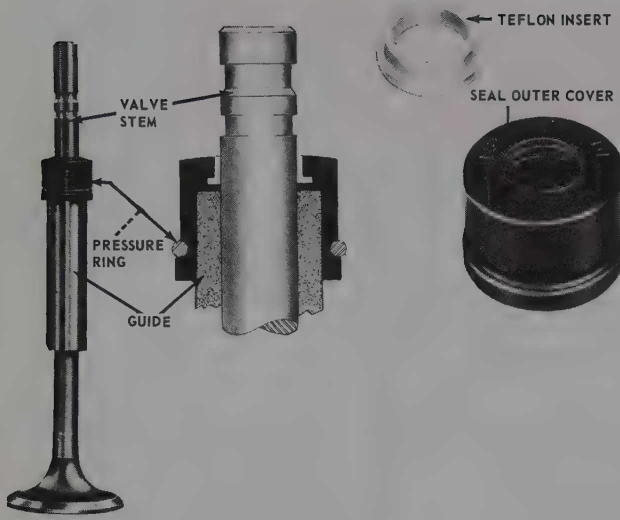

TEFLON INSERT
SEAL OUTER COVER
VALVE STEM
PRESSURE RING
GUIDE

Fig. 13-42. Teflon valve guide oil seal.

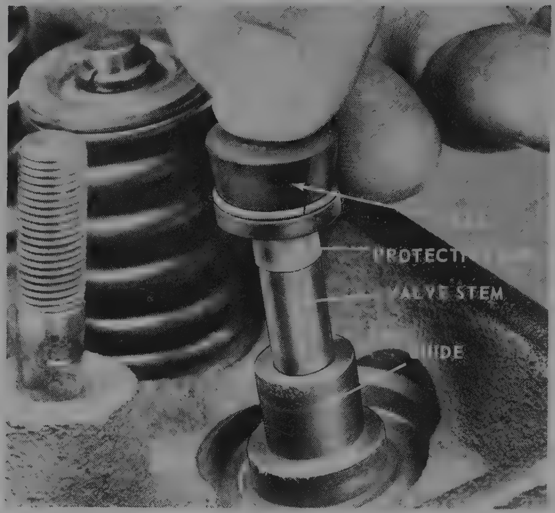

PROTECTI
VALVE STEM
GUIDE

Fig. 13-44. Pressing seal over protective cap on valve stem end.

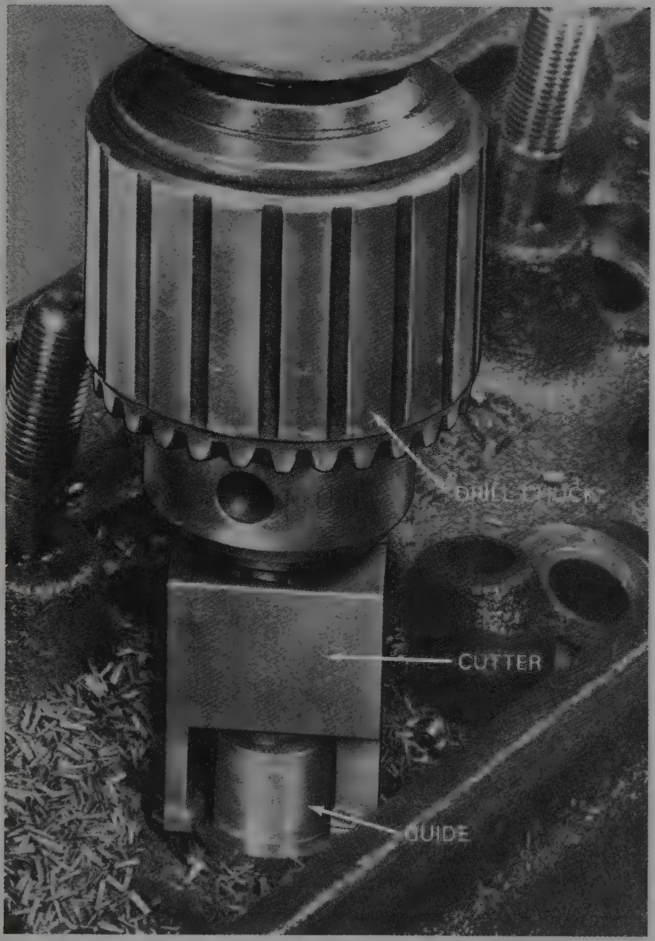

DRILL CHUCK
CUTTER
GUIDE

Fig. 13-43. Machining a valve guide for seal installation. (Perfect Circle)

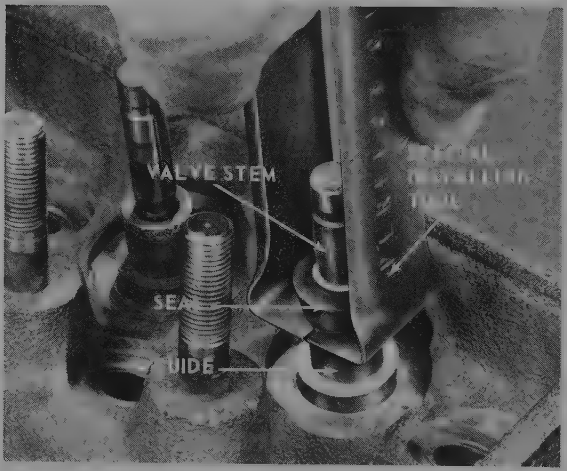

VALVE STEM
SPECIAL INSTALLING TOOL
SEAL
GUIDE

Fig. 13-45. Seating valve guide seal.

cylinders during the intake stroke, the exhaust valve is also subjected to a mild vacuum. This vacuum is caused by the exhaust gases rushing over the head of the guide.

As the overhead valve design dominates the field, oil control through the guides is critical. Great quantities of oil are pumped to the rocker arms. A considerable amount finds its way to the valve stem end.

The combined forces of gravity, inertia, and vacuum attempt to draw the oil down through the guides. See Fig. 13-46.

In addition to the special guide seal shown, protective shields or "umbrellas" and neoprene rings are often used on the valve stem end to prevent oil from flowing down the stem to the guide. Valve guides are often cut at an angle to prevent oil from puddling on the top.

When installing the valve assembly, be careful to avoid damage to the seals. Occasionally, only the intake valves are protected with guide seals, tapered guide heads, and stem end shields. Make sure they are correctly installed, Fig. 13-47.

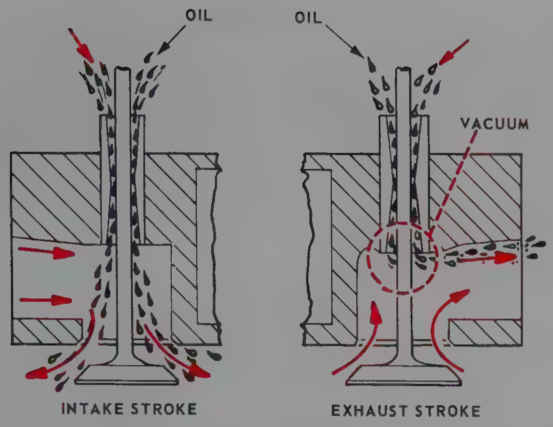


Fig. 13-46. Both intake and exhaust guides will pass oil.

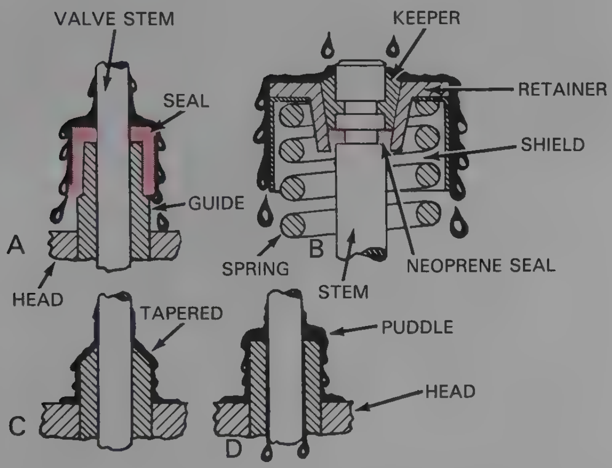


Fig. 13-47. Devices used to prevent oil consumption through guides. A—Guide seal. B—Neoprene seal and shield. C—Tapered guide top. D—Note how square cut guide allows oil to puddle and run through guide.

CHECKING VALVE SEATS

Inspect each valve seat for signs of excessive burning or cracking. If the seat is of the insert type (special steel ring pressed into head) and looseness, burning, or cracking is present, it must be removed and replaced with a new ring.

If the seat is of the integral type and is cracked or badly burned, it must be cut out and an insert installed.

REMOVING VALVE SEAT INSERT

A special chisel or mechanical puller may be used to pull the seat. When removing, be careful not to damage the seat recess. Refer to Fig. 13-48.

INSTALLING VALVE SEAT INSERT

Make certain you have the correct size insert. Outside diameter, depth, and inside diameter should match that of the insert being replaced. Look at Fig. 13-49.

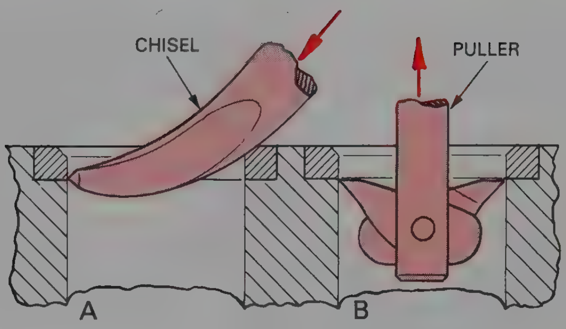


Fig. 13-48. Removing valve seat inserts. A—Special chisel. B—Mechanical puller.

If the original inserts were cast iron, cast iron replacements can be used. If a hard type insert (special heat resistant steel such as Stellite) is removed, replace with a similar type.

The recess must be clean and free of nicks and dents. Place a special driver pilot in the valve guide. Install a driving head on the driver. Head should be just a little smaller than the insert OD.

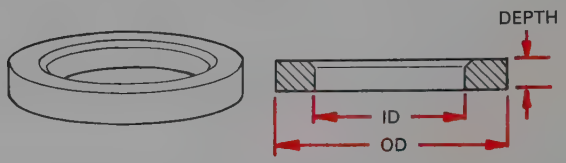


Fig. 13-49. Replacement seat insert must be of correct size.

Lay the insert, beveled edge down, over the recess. Freezing will reduce the OD and assist installation. Slide driver over pilot and start insert with several firm blows. As the insert nears the bottom, reduce the strength of the hammer blows. By listening to the sound of hammering, you can tell when the insert is fully seated. DO NOT CONTINUE POUNDING AFTER FULLY SEATED. Fig. 13-50 shows a cross section of a typical insert driver set up for work.

The insert OD will be one or two thousandths larger than the recess. This will produce an interference (tight) fit to assist in securing the insert. It will also produce good heat transfer from insert to head.

If the inserts have been chilled in Dry Ice, with Freon, or in the freezer, remove them one at a time and install. If all are removed they will warm up before installation.

Soft gray cast iron inserts have the same coefficient of expansion as the head metal (when cast iron). If properly fitted, will not have to be peened (upsetting head metal around insert OD to hold it in place). Many mechanics peen ALL types of inserts to provide an extra measure of safety.

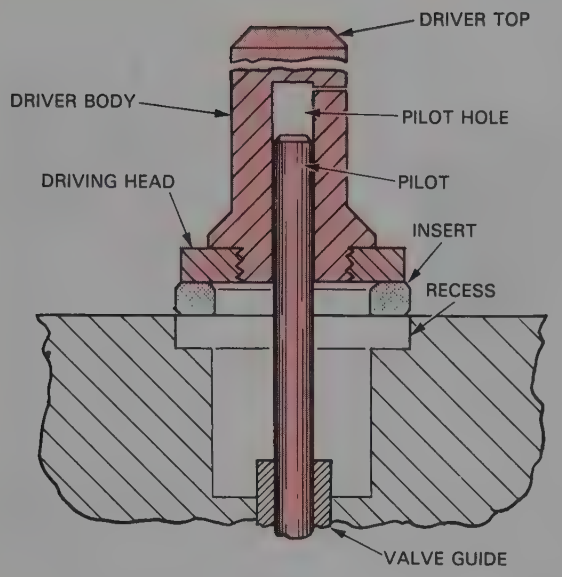


Fig. 13-50. Installing valve seat insert with a special pilot and driver combination.

PEENING INSERT

The head metal around the OD of the insert may be either peened (hammered) or swaged (upset by a rolling or rubbing action). All hard inserts, and all inserts set in an aluminum head, must be peened or swaged. The insert will have a small chamfer on the upper OD into which the head metal is forced.

For peening, a pilot is placed in the valve guide, and a special peening tool body is dropped over the pilot. The peen is adjusted so it contacts the head metal along the edge of the insert. By turning and hammering the peening tool, the metal will be upset (bulged). Other tools apply a rolling pressure to swage the metal into the chamfer, Fig. 13-51.

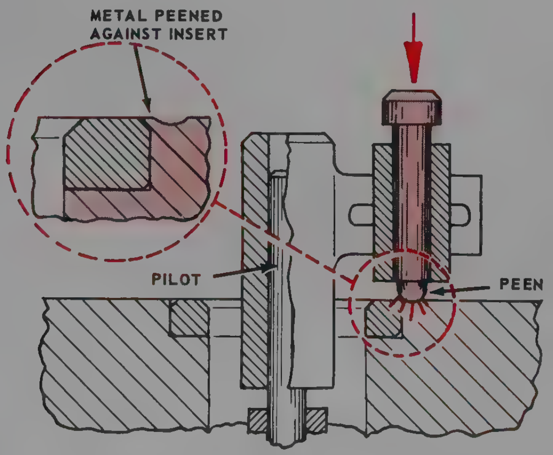


Fig. 13-51. Using a special tool to "peen" the metal around insert edge. Note how metal is forced against insert.

CUTTING RECESS FOR INSERT SEAT

Where no insert was used and the integral seat is damaged beyond repair by grinding, a recess may be cut and an insert seat installed. In cases where an insert is used but is loose, a recess may be cut for an insert of slightly larger OD.

SELECT PILOT AND CUTTER

Select a pilot that fits the guide (guide should be in good shape) as recommended by the tool manufacturer. Choose a cutter of the correct size and install, Fig. 13-52.

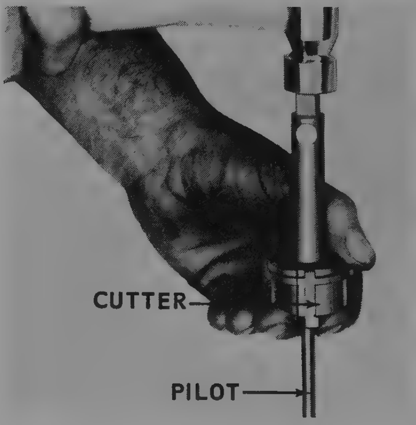


Fig. 13-52. Installing valve seat insert recess cutter on a pilot. (Albertson-Sioux)

INSTALL PILOT, ALIGN, AND SECURE TOOL

The pilot assembly is fitted to the guide. The body of the tool is dropped over the pilot. All alignment screws must be loose.

The anchor bolt slot is placed over a convenient head bolt hole and the anchor bolt installed. Give the tool body a slight shaking motion (all screws loose) to allow it to align with the pilot, Fig. 13-53.

Lock the anchor bolt securely. Lock the other screws. When all are secured, the cutter should revolve with finger pressure. If binding is present, loosen screws, readjust, and retighten. The object is to have the tool body and drive mechanism secure without binding the pilot and cutter assembly, Fig. 13-53.

ADJUST CUTTING DEPTH

With the cutter just touching the work, place the insert ring on the stop block. Run the stop collar down until it touches the ring. Lock the feed screw to the cutter sleeve and remove the ring. The cutter will then cut to the exact depth of the ring, Fig. 13-53.

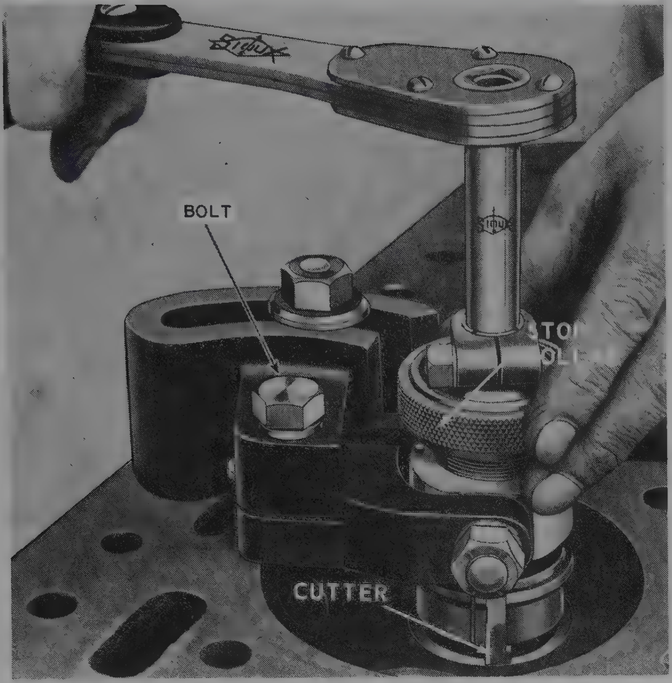


Fig. 13-53. Cutting the insert recess.

CUT RECESS

Make certain all alignment screws are tight. Use either a ratchet handle, or a power drive mechanism to rotate the cutter.

With the cutter just clearing the work, start turning. Feed the cutter into the work by turning the knurled stop collar. Do not force the cutter. Give several turns, and then run the cutter lightly down. Repeat this process until stop collar engages the stop block. At this point, give the tool a few additional turns to produce a smooth seat for the insert. Run the cutter out of the recess and remove tool.

Fig. 13-53 shows the mechanic moving the cutter into the work by turning the stop collar. Fig. 13-54 illustrates a power driven cutter tool.

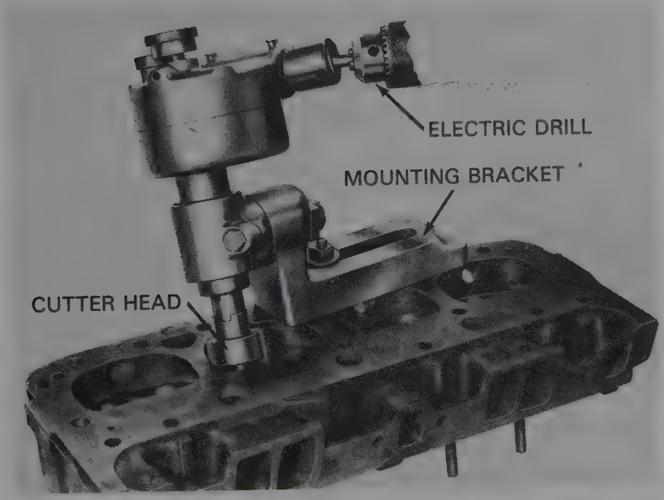


Fig. 13-54. Using a power driven valve seat recess cutter. (Kwik-Way)

VALVE SEAT

The valve seat must be cut at correct angle, be smooth, clean, and free of cracks, nicks, and pits. It must be the correct width, and engage the face of the valve near its central portion.

Common seat angles are 45 and 30 deg. Where an interference fit is desired, the interference angle may be ground on either the seat or the valve. Follow manufacturer's specs.

Seat width varies (see manufacturer's specs) but will average around 1/16 in. (1.58 mm) for both intake and exhaust. A seat that is too narrow will pound out of shape more easily. It will also fail to dissipate enough heat from the valve face. A seat that is too wide will tend to collect carbon, eventually preventing a good seal with resultant valve overheating and burning. See Fig. 13-55.

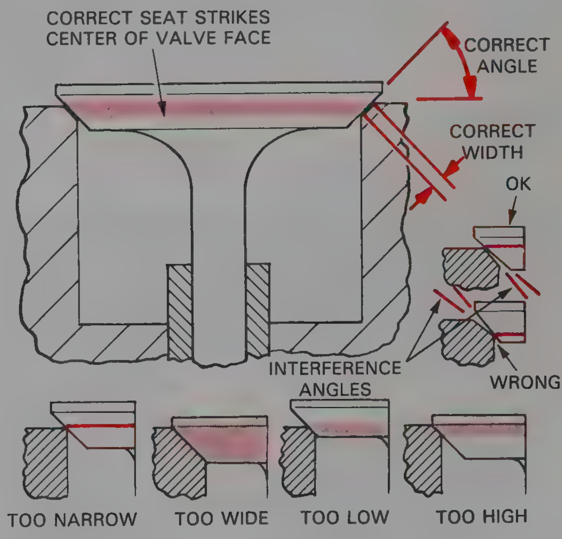


Fig. 13-55. Correct and incorrect valve seats. Note interference angles.

When refacing a seat, the removal of stock will widen the seat beyond original specifications. It must be narrowed by removing metal from the upper portion. Look at Fig. 13-56.

In cases where the valve port walls narrow, or are uneven, metal will have to be removed from the bottom also. If the walls are smooth and of constant diameter, only a very LIGHT cut with a 60-70 deg. stone should be taken. If inserts are used, the bottom cut is not necessary, Fig. 13-57. The light bottom cut will produce a seat that is the same width at all spots.

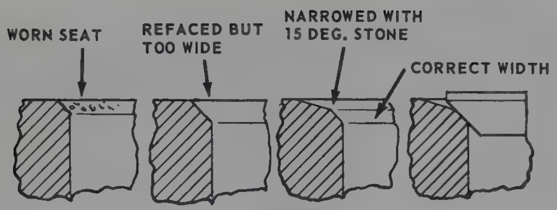

WORN SEAT
REFACED BUT TOO WIDE
NARROWED WITH 15 DEG. STONE
CORRECT WIDTH

Fig. 13-56. Narrowing valve seat width after refacing. A 30 deg. stone is occasionally used to narrow 45 deg. seats. Sometimes a flat stone is required.

REFACING VALVE SEAT

After all valve guide and insert work is complete, the valve seats are ready to be refaced. The seat must be free of carbon, oil, and dirt. If not clean, the grinding stone will quickly load (pores of stone fill up with debris), thus ruining the cutting action.

The valve guides must be spotlessly clean to allow the pilot to properly align with the guide hole. Refacing can be done either with stones or hardened cutters.

SELECT PROPER STONE

Seat stones are available in various widths. Coarse textured roughing stones are used for the initial or roughing cut on steel seats. The fine textured finishing stone is used for the last cut on steel seats. The cast iron block or head requires only the use of the finishing stone. For grinding Stellite and other hard seat inserts, a special stone is available.

The stone must be a little wider than the finished seat in order to prevent counterboring. It must not be so wide as to strike other parts of the combustion chamber. Fig. 13-58 illustrates how various widths affect the job.

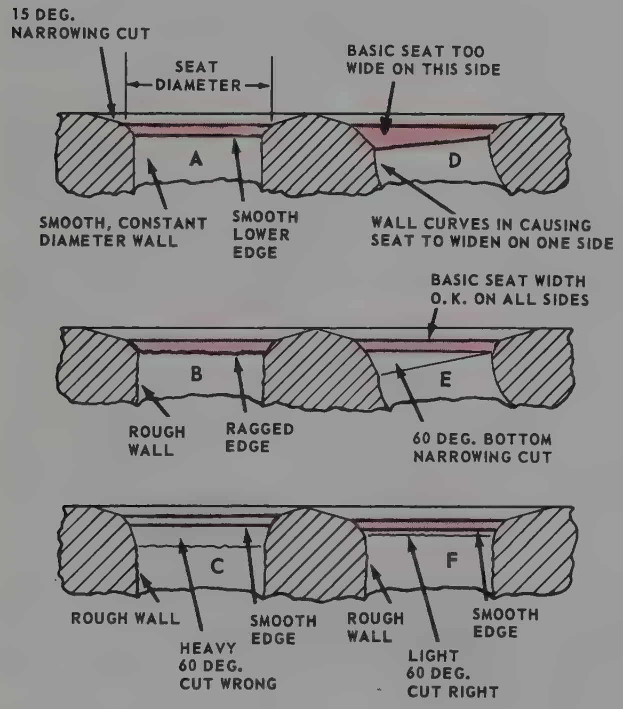

15 DEG. NARROWING CUT
SEAT DIAMETER
BASIC SEAT TOO WIDE ON THIS SIDE
A
D
SMOOTH, CONSTANT DIAMETER WALL
SMOOTH LOWER EDGE
WALL CURVES IN CAUSING SEAT TO WIDEN ON ONE SIDE
BASIC SEAT WIDTH O.K. ON ALL SIDES
B
E
ROUGH WALL
RAGGED EDGE
60 DEG. BOTTOM NARROWING CUT
C
F
ROUGH WALL
SMOOTH EDGE
HEAVY 60 DEG. CUT WRONG
ROUGH WALL
LIGHT 60 DEG. CUT RIGHT
SMOOTH EDGE

Fig. 13-57. Narrowing valve seat. A—15 deg. cut from top makes a good seat when port walls are smooth and of constant diameter. B—Rough wall leaves a ragged lower edge on seat. C—Heavy bottom cut produces smooth lower seat edge but widens seat diameter. D—Curved port walls produce an uneven seat width. E—Bottom cut produces an even width. F—Very light bottom cut smooths seat edge without appreciable increase in seat diameter.

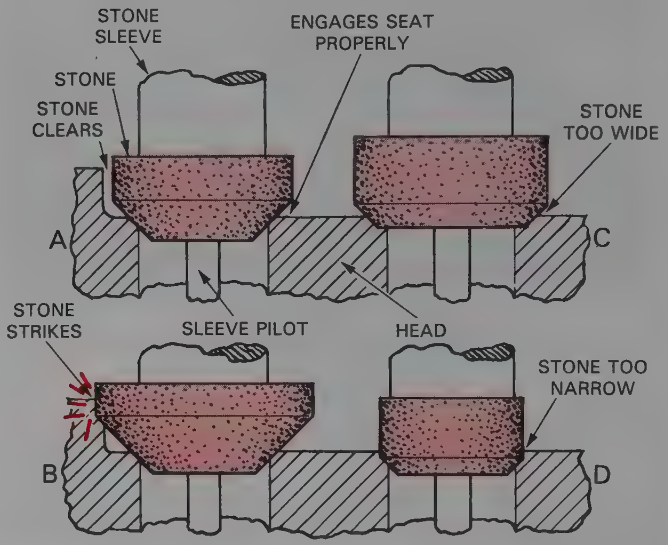

STONE SLEEVE
ENGAGES SEAT PROPERLY
STONE
STONE CLEARS
STONE TOO WIDE
A
C
STONE STRIKES
SLEEVE PILOT
HEAD
STONE TOO NARROW
B
D

Fig. 13-58. Stone must be of correct width. A—Stone OK. B—Too wide. C—Too wide, makes horizontal step at bottom of seat. D—Too narrow, makes vertical step at top of seat.

DRESSING STONE

After selecting a stone of the correct size and texture, screw the stone snugly on the stone holder or sleeve. If one is available, select a stone with the correct angle. This will save time in dressing and will prolong the life of the stone. Many stones are constructed so that an angle may be ground on both ends, Fig. 13-59.

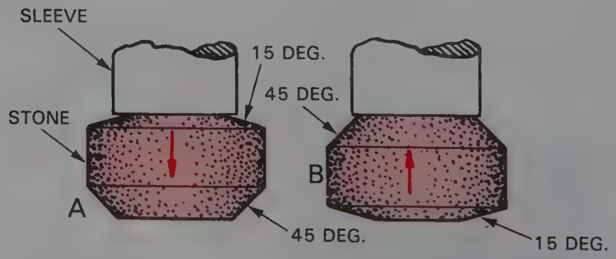

SLEEVE
15 DEG.
45 DEG.
STONE
B
A
45 DEG.
15 DEG.

Fig. 13-59. Some stones can have an angle dressed on both ends. A—Stone with 45 deg. angle down. B—Same stone, reversed, with 15 deg. angle down.

Place stone sleeve on the dressing stand pilot. Adjust the stand diamond holder to the correct angle. Lock all adjustments.

Back diamond away from stone. Engage sleeve drive motor and spin stone. Run the diamond tip across the full face of the stone. Take light cuts until the angle is correct and the full stone face is clean and true. See Fig. 13-60.

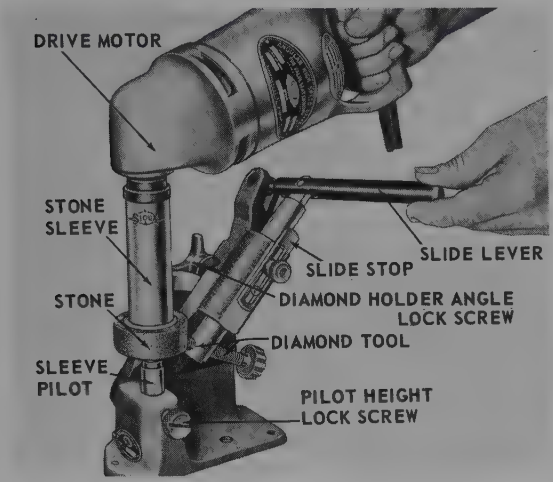


Fig. 13-60. Dressing stone using a typical dressing stand. (Albertson-Sioux)

DO NOT RUIN DIAMOND BY UNDERCUTTING

Use care when dressing to see that the first cut is not too heavy. The full stone angle must also be dressed to prevent injury to the diamond. Fig. 13-61 illustrates the effects of both an intital heavy cut and failure to dress the full width.

INSTALL STONE SLEEVE PILOT

There are basically two types of stone pilots in use. One is the ADJUSTABLE type that is slipped into the guide and then expanded. The other is of TAPERED CONSTRUCTION that is secured through friction between the guide and a tapered section.

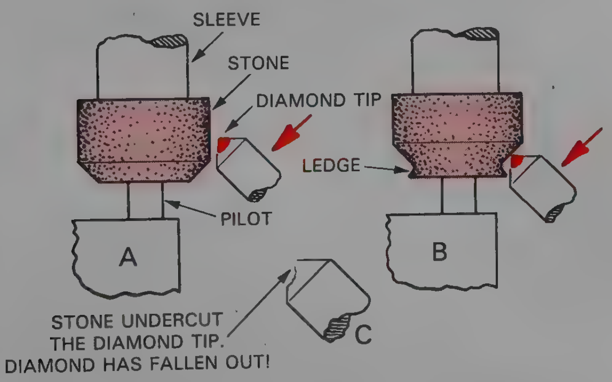


Fig. 13-61. Do not ruin the diamond. A—Heavy cut will strike steel below diamond. B—Failure to dress full width leaves a ledge that can strike steel beneath diamond. C—When steel beneath diamond is undercut, diamond tip will fall out.

Regardless of the type used, make sure that the guide is clean. Wipe off the pilot with a clean, lightly-oiled rag, and insert the pilot. The pilot must be RIGID. See Fig. 13-62.

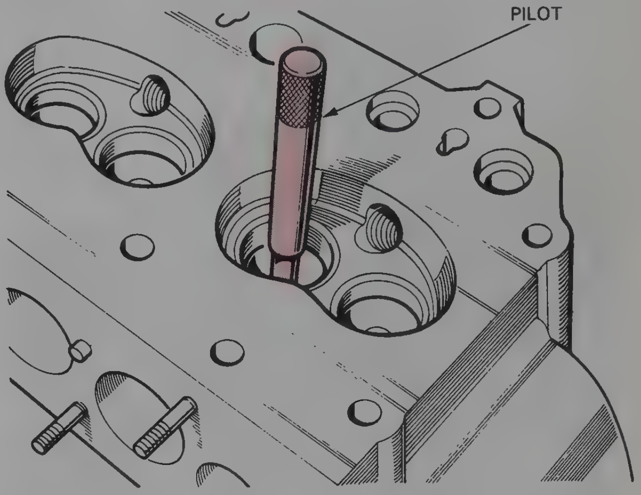


Fig. 13-62. Valve seat stone sleeve pilot in place in valve guide. Pilot must be tight. (British-Leyland)

USE TWO OR MORE SLEEVES

Mount the correct seat angle stone on one sleeve and the 15 deg. and 70 deg. stones on two other sleeves. This will allow you to grind and narrow the seat without removing and changing stones. Once the pilot is inserted, finish the complete seat operation before moving to the next one.

GRINDING SEAT

Using a clean, dressed stone, place the sleeve on the pilot. The stone should contact the seat, as in Fig. 13-63.

Insert drive motor head into end of sleeve. Tilt motor up, down, and sideways to feel for a nonbinding, central position. While supporting weight of motor, engage switch. Allow stone to grind for a few seconds. Then, stop and remove motor. Raise sleeve and examine seat. Repeat until seat is smooth, clean, and free of burns and pits. CAUTION: REMOVE ONLY ENOUGH STOCK TO CLEAN SEAT! IF INTEGRAL SEAT IS HARDENED, EXCESSIVE GRINDING CAN CUT THROUGH THE HARDENED AREA. Check manufacturer's specifications.

On hard inserts, dress stone several times for each seat. NEVER CONTINUE GRINDING WHEN STONE SURFACE NEEDS DRESSING.

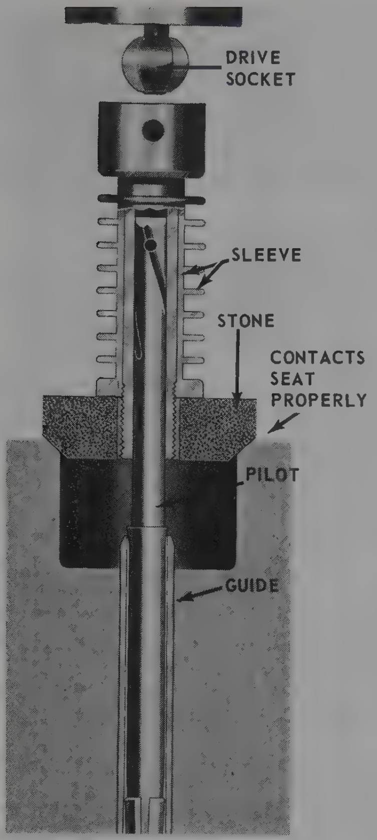


Fig. 13-63. Stone and sleeve in place on pilot. Note correct seat contact. (Black and Decker)

If using a roughing stone, stop when the seat is cleaned up. Switch to a finishing stone and polish up the seat. REMEMBER: THE FINISHED SEAT WILL BE ONLY AS ACCURATE AS THE STONE, Fig. 13-64.

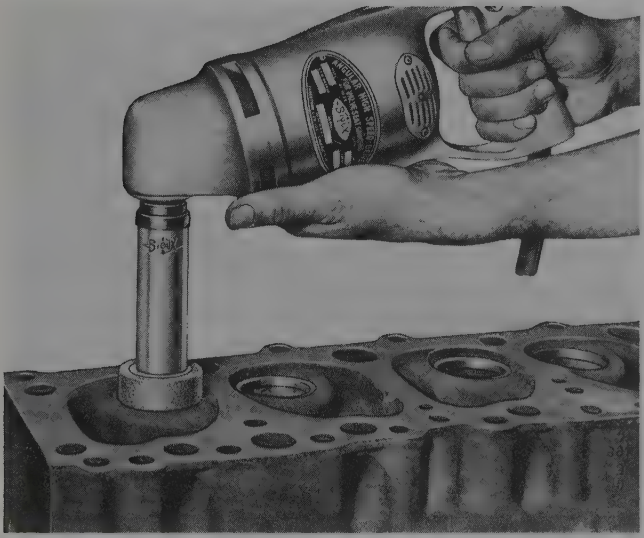


Fig. 13-64. Grinding valve seat. Note how operator supports weight of drive motor with left hand.

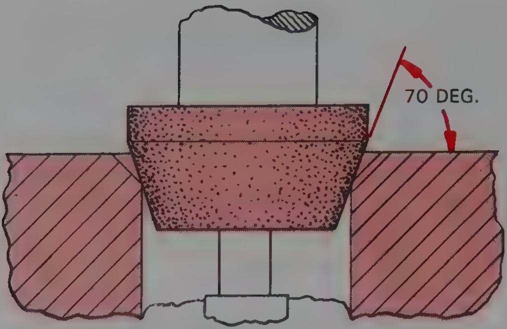


Fig. 13-65. Taking a LIGHT cut on bottom of seat with a 60-70 deg. stone.

NARROWING SEAT

Using a 60-70 deg. stone, grind until the 60-70 deg. angle touches the basic 30-45 deg. seat surface all the way around. This 60-70 deg. stone cuts very quickly. Do not apply down pressure and cut for only about two seconds before checking, Fig. 13-65.

With the 15-30 deg. stone, (see manufacturer's specs) remove stock until the seat is down to the specified width. See Fig. 13-66.

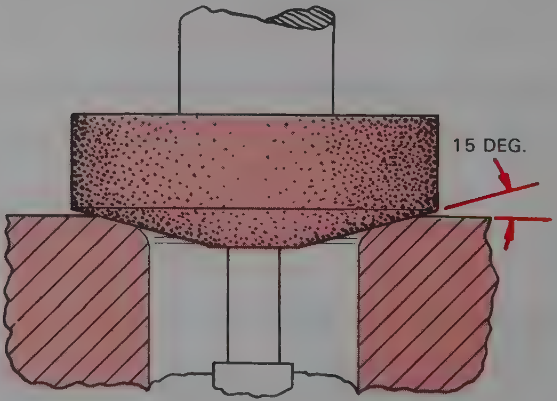


Fig. 13-66. Narrowing seat to specified width by removing metal from top with a 15 deg. stone.

A small measuring tool, such as shown in Fig. 13-67, will assist in a careful measurement of seat width. Use a light and be accurate.

A trick often used for seat grinding is to mark the seat (after grinding basic angle) with a series of soft pencil marks across the width. When removing stock from above and below the seat, the pencil marks will clearly show what is left of the basic angle, Fig. 13-68.

TESTING VALVE SEAT

To test a valve seat for concentricity (true roundness) place a special valve seat dial indicator on the pilot.

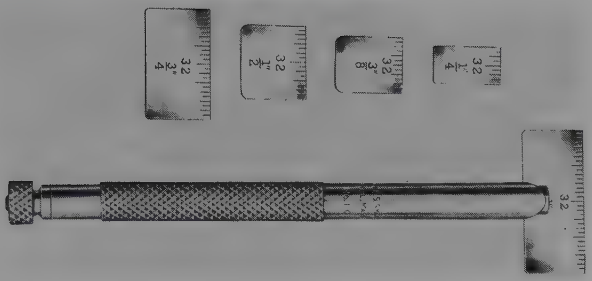


Fig. 13-67. A handy seat width measuring tool. (Starret)

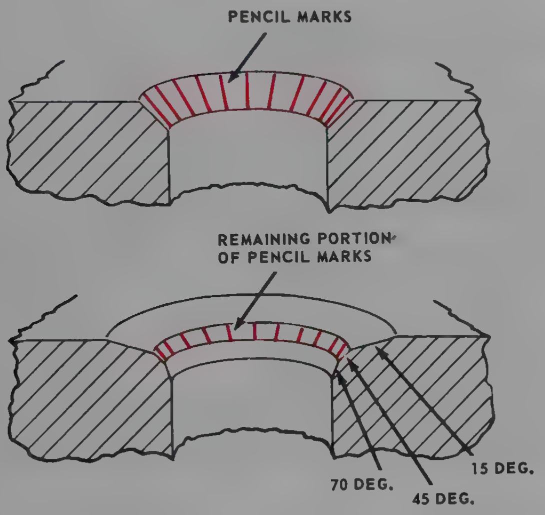


Fig. 13-68. Using pencil marks to help determine width of basic 30 or 45 deg. seat.

Adjust the indicator bar so that it contacts the center of the valve seat. The dial needle should travel about a half turn when the bar length is correct. Set the dial to 0. Hold the upper dial section and slowly turn the bottom section around so the bar travels completely around the seat. The dial needle will indicate any runout. The entire seat should be within .002 in. (0.05 mm).

If runout exceeds .002 in. (0.05 mm), check the setup carefully (bar tip should be in center of seat) and try again. If runout still prevails, regrind the seat, Fig. 13-69.

VALVE LAPPING

There are two schools of thought regarding lapping the valve into the seat with lapping compound (fine abrasive powder). Some feel that it produces a more accurate seal between valve and seat while others contend that it is of no value.

Many authorities agree that when modern valve grinding equipment, in good condition, is properly used, that lapping is NOT necessary. Lapping when an interference fit is desired, can actually damage the seal.

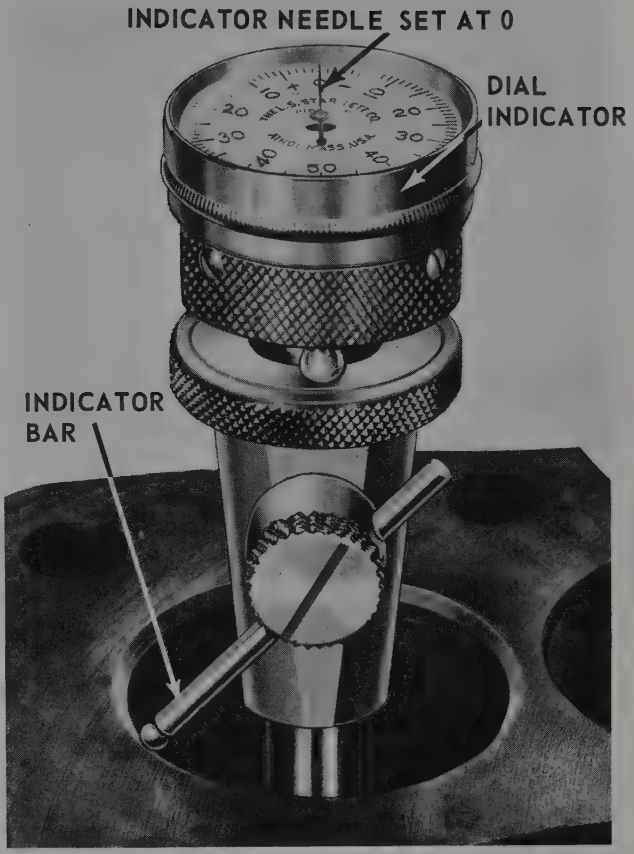


Fig. 13-69. Checking valve seat concentricity with a dial indicator.

FINAL CHECK FOR CONCENTRICITY OF BOTH SEAT AND VALVE FACE

Rub a very thin film of Prussian blue on the valve face. Place the valve in position. While pressing (in center) against the seat, rotate the valve about one-fourth turn to the right and then back to the point of beginning. Remove the valve and examine the seat. It should be marked with blue around its entire circumference. The seat should mark the valve face near the center.

Pencil marks, about 1/4 in. (6.35 mm) apart around the valve face will also provide a check. The one-fourth turn to the right and then to left should wipe out all marks. Before checking by placing valves in the guides, the head and the guides should be thoroughly washed, flushed, and blown dry, Fig. 13-70.

REPLACING ROCKER ARM STUD

If the cylinder head uses individual rocker arm ball studs, check them for signs of damage or looseness. If a replacement is necessary due to breakage, a standard size replacement will suffice. If the stud is loose, the hole will have to be reamed for one of several available oversizes.

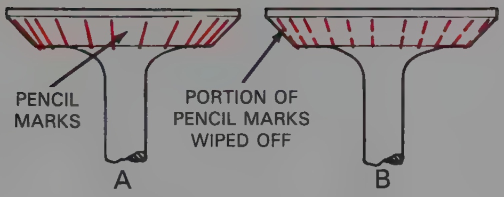


Fig. 13-70. Pencil marks on valve face will determine valve face-to-seat accuracy. A—Marks applied. B—Portion of marks wiped off by placing valve in seat and giving it one-quarter turn.

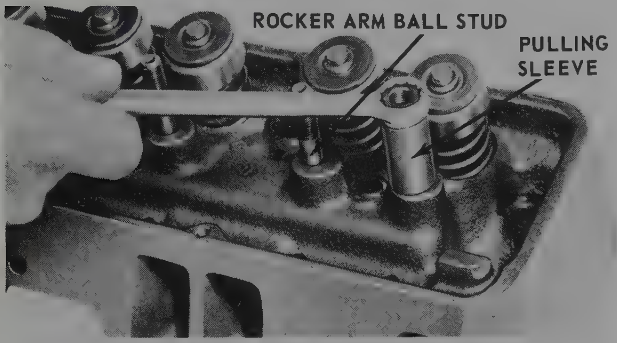


Fig. 13-71. Pulling a rocker arm stud. (G.M.C.)

To remove the stud (if broken off at boss, drill and remove with a stud extractor) place the pulling sleeve over the stud. Run the nut down against the sleeve. Continue turning to pull the stud, Fig. 13-71.

If an oversize stud is required, ream the hole with a special reamer of the correct size. If the larger oversize is needed, ream the hole in two steps. Use the smaller oversize reamer first, then finish with one of the desired size. See Fig. 13-72.

Thread the replacement stud in the driver. Coat the plain end with hypoid lubricant or Lubriplate. Place over the hole and drive down until driver body touches stud boss. This will be the correct depth. Remove driver tool, Fig. 13-73.

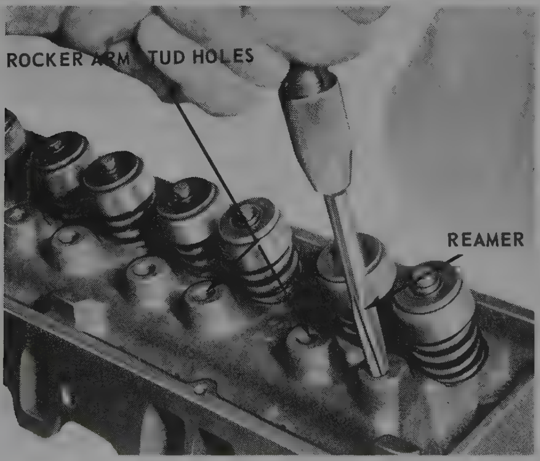


Fig. 13-72. Reaming rocker arm stud hole.

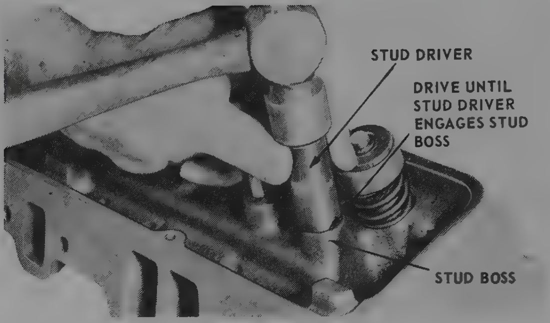


Fig. 13-73. Driving rocker arm stud into place.

CLEANING VALVE SPRINGS

Valve springs should be soaked in solvent, brushed, and thoroughly rinsed. Never clean springs that are painted in strong cleaners as the paint will be removed. The paint and other coatings prevent rust. Wire power wheels will also remove this protective coating. Spring life will be shortened.

CHECK SPRING TENSION

After extended service, valve springs tend to lose tension. Since correct tension is important to proper valve action, each spring must be tested to make certain it meets minimum requirements. Manufacturers provide specifications listing the amount of pressure, in pounds or kilograms, that a given spring should exert when compressed to a specific length.

The spring is placed in an appropriate measuring device and compressed to the specified length. The pressure in lbs. or kg is then determined, Fig. 13-74.

CHECK VALVE SPRING FREE LENGTH AND SQUARENESS

Place the spring on a flat surface. Slide a combination square up to the spring (do not tip spring). Using

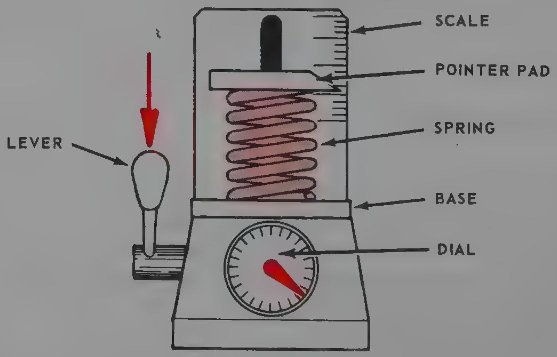


Fig. 13-74. Testing valve spring tension. Spring is placed on base. When lever is pulled down, pointer pad compresses spring to specified distance on scale. Tension is then read on dial.

the scale on the blade, measure the free length (length when spring is not under pressure). It should meet specs.

Carefully sight between the edge of the spring and the blade. The spring should be parallel to the blade. Give the spring a partial turn and check again. If both sightings indicate that the spring is parallel (not more than 1/16 in. (1.59 mm) difference between top and bottom), you can assume that the spring is square. Place on the opposite end and check it for squareness, Fig. 13-75.

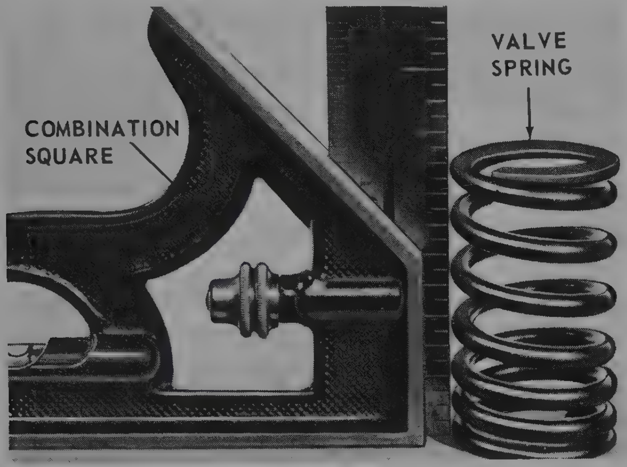


Fig. 13-75. Checking spring free length and squareness. (Plymouth)

INSPECT SPRING FOR ETCHING OR OTHER DAMAGE

Check the spring for any signs of rusting, corrosive etching, and for scratches or nicks.

CHECK DAMPER SPRINGS AND CLIPS

Inspect damper springs (used inside regular spring to reduce spring vibration) and damper clips if used. Discard any that are worn or fail to meet specs.

POOR SPRINGS ARE EXPENSIVE

Reject springs that fail to meet specified compressed pressure, free length, squareness, or that show other problems.

A weak spring will cause valve float (valve closing so slowly that lobe on camshaft starts to open it again before it has fully seated). Valves may start sticking in the guides causing heavy tappet noise, missing, burning, and broken valves.

Remember that using poor valve springs can be expensive. New springs are inexpensive and will certainly raise the level of reliability and performance.

CHECKING CYLINDER HEAD FOR WARPAGE

To insure the close fit necessary between head and block, the head should be checked for warpage. Some warpage, around .003 in. (0.08 mm) in any six in. (152.4 mm) or .006 in. (0.15 mm) overall, is permissible. Distortion beyond this point should be corrected by grinding or milling a small amount from the surface. See manufacturer's specs for permissible amount to be removed.

Removal of metal from the head or block will reduce the size of the combustion chamber (in most engines), thus raising the compression ratio. It will also change the effective length from the lifters to the rocker arms. On an overhead camshaft engine, the timing chain length will be altered.

Special head gaskets, thicker than standard, are available to maintain compression and working dimensions when stock has been removed from head or block.

Fig. 13-76 shows the use of a straightedge for checking cylinder head surface accuracy. The straightedge is placed across the head as shown. Sight along the edge to detect any warpage. If necessary, slide a feeler gauge between the straightedge and the head to determine the amount of distortion. Head surface must also be free of nicks, scratches, and gasket cement.

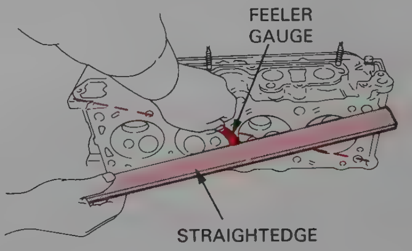


Fig. 13-76. Checking cylinder head surface for warpage.

INSTALLING VALVES, SEALS, AND SPRING ASSEMBLIES

With the cylinder head in a suitable fixture and spotlessly clean, oil the valve guides. Select the proper valve, oil the stem, and insert into the guide.

On engines that do not have provisions for adjusting rocker arm-to-push rod clearance, the height of the valve stem from the head should be checked. In that removal of metal from the valve face and seat will allow the stem to protrude further, the rocker arm will be tipped down on the push rod side, thus forcing the hydraulic lifter plunger near the bottom of its travel. If provisions are not built into the lifter to adjust to this change, malfunctions can result. If the height of the stem is excessive, the valve must be removed and the stem end ground down the proper amount. Check all valves, Fig. 13-77.

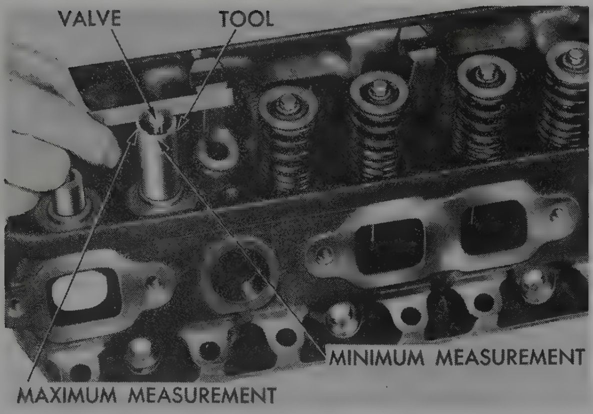


Fig. 13-77. Checking valve stem height. (Dodge)

While holding the valve in place, install stem-to-guide oil seal, if used. If required, place steel washer around guide and in contact with head. Check springs for a closed coil end (one end of spring may have coils spaced closer together). Place closed end toward the head, over the stem, and in contact with the head, Fig. 13-78.

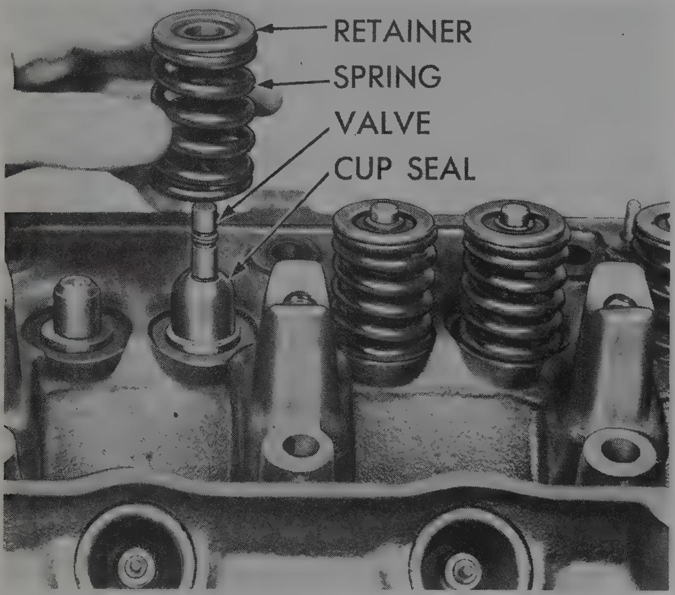


Fig. 13-78. Guide seal (cup seal) installed. Spring and retainer being placed in position. (Chrysler)

If dual coils or a damper spring are used, space coil ends per manufacturer's instructions (usually about 180 deg. apart).

Install shield or umbrella and retainer over the spring. Using a spring compressor, compress the spring just far enough to expose the stem oil seal groove. Slip the seal into the groove. Make sure it is properly positioned and is not twisted. Insert the split keepers or locks and slowly release the spring. As the spring rises, guide the retainer so it is centered around the keepers. When fully released, check keepers to make certain they are fully engaged. IF KEEPERS ARE NOT LOCKED INTO POSITION, THEY CAN SLIP AND FLY OUT WITH DANGEROUS FORCE. KEEP YOUR FACE TO ONE SIDE, Fig. 13-79.

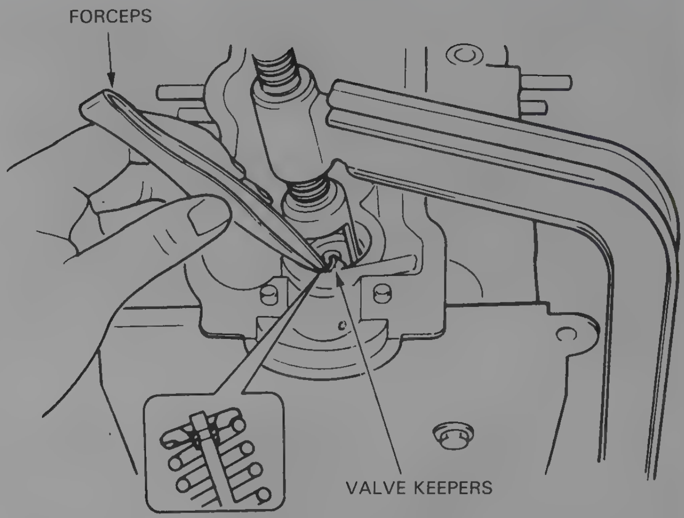


Fig. 13-79. Compressing valve spring and installing split valve keepers. (GM)

Each valve should be installed in the port from which it was removed unless either the guide or valve is new. On some engines, there are differences between intake and exhaust springs and retainers. Be careful to assemble them in the proper locations. Fig. 13-80 shows a typical valve stem assembly. Note the stem seal.

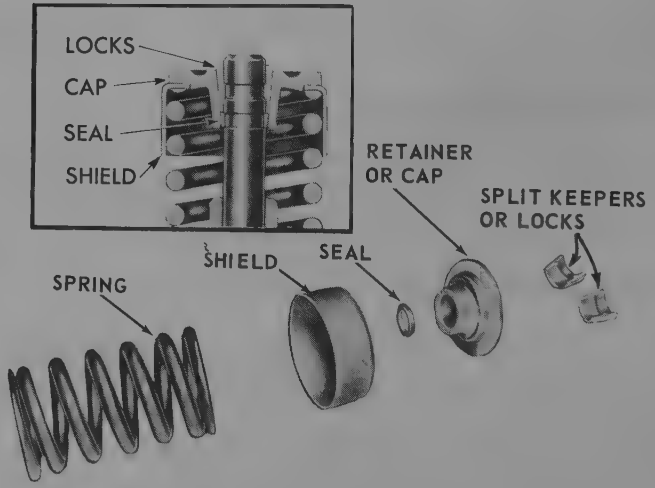


Fig. 13-80. Typical valve spring assembly.

TEST STEM SEAL

When a stem seal is employed, it may be tested by placing a small suction cup over the retainer. Squeeze

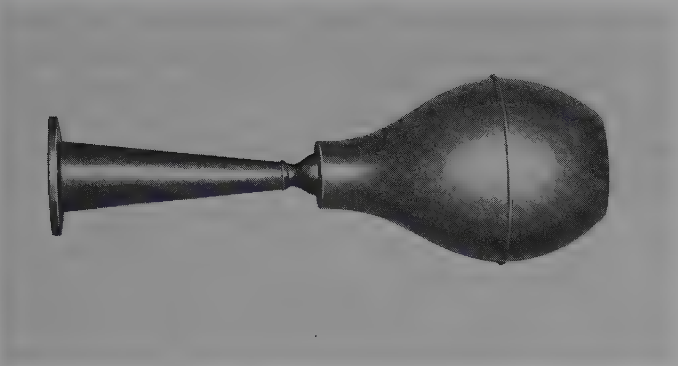


Fig. 13-81. Valve stem seal test tool. (Chevrolet)

the bulb while holding the cup against the assembly. When the bulb is released, it should stay compressed thus indicating an airtight seal. Such a test tool is shown in Fig. 13-81.

CHECKING INSTALLED HEIGHT OF VALVE SPRING

As with the valve stem end, removal of stock from valve face and seat will allow the keeper grooves to protrude higher above the head. This will increase the installed length of the spring, thus reducing spring tension. Using specs, measure the installed height of each spring, Fig. 13-82.

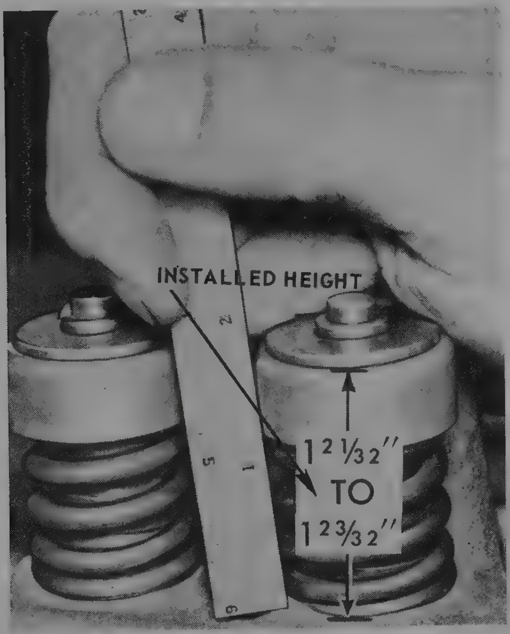


Fig. 13-82. Checking valve spring installed height.

If the height is excessive, it must be corrected by removing the spring, and placing a special steel washer or insert between the spring and the head. These washers are available in different thicknesses. Do not install washers that are too thick, as the spring pressure can be increased to the point of causing rapid lifter and camshaft wear. Fig. 13-83 illustrates one type of washer used to compensate for excessive stem length.

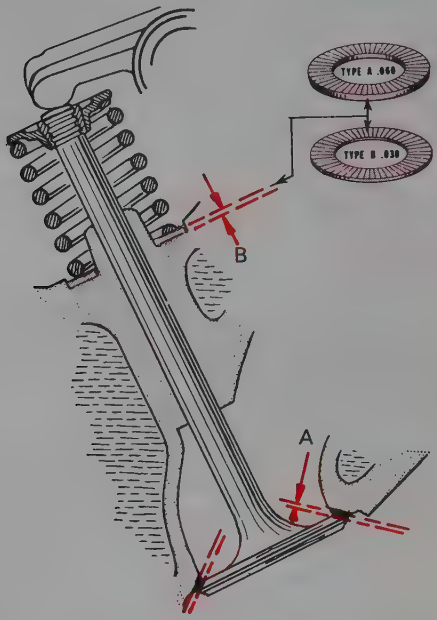


Fig. 13-83. Correcting excessive valve spring installed height by adding a washer between head and spring end. A—Amount of metal removed by grinding valve and seat. B—Washer thickness comparable to A. (Dodge)

INSTALLING CYLINDER HEAD

When the ball joint rocker arms are used, the rockers may be attached loosely to the rocker studs and left in this position while the head is installed. Generally the rocker shaft and arm assembly is installed after the head is in position and has been torqued.

The block must be within acceptable distortion measurements. The surface must be absolutely clean and free of nicks and dents. All head bolt holes should be clean.

If the block does not have built-in guide pins, make them out of old cylinder head cap screws. Cut off the heads of the bolts and file screwdriver slots in the tops. Taper the cut end of each so it will enter the head easily. Screw them into the block, one near each end.

Place the cylinder head gasket on the block. Check for right side up and front end to front of engine. Also, check to ascertain that all passages are exposed, and that the gasket fits properly.

Lay the gasket, upper surface down, on a clean surface. Coat gasket with a thin layer of the proper cement. Place the cemented side against the block and carefully coat the top side. Use a THIN coat only and do not let cement run into passageways or cylinders.

Some gaskets come with a special coating that pro-

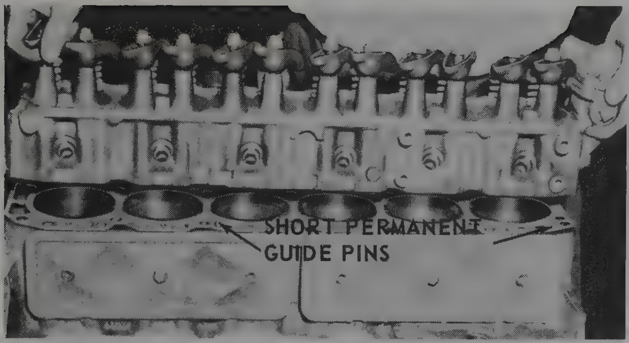


Fig. 13-84. Lowering cylinder head into position. Note permanent short guide pins. (G.M.C.)

vides a seal as soon as the engine is warmed up the first time. Cement is not required on this type of gasket. See manufacturer's specs.

Place the head into position and lower over guide pins. Figs. 13-84 and 13-85 illustrate the use of guide pins to align cylinder head, gasket, and block surfaces.

Coat the head cap screw threads (after wire brushing) with a suitable thread compound. The compound should have the necessary sealing properties, especially when cap screws thread into a hole that enters the water jacket.

Insert the cap screws in their proper locations. Watch for different lengths. If one of the cap screws is designed to pass oil from the block through the head to the rocker assembly, be certain it is placed in the correct spot.

Run all bolts down until they just engage the head. Remove guide pins and install bolts in these holes.

TORQUE HEAD BOLTS

Using a torque wrench and following the recommended sequence, bring all bolts up to one third torque. Go over them again bringing to two thirds torque. They should then be brought to full torque. A fourth time over will make sure none have been missed. Remember that proper torque is a MUST. Excessive or uneven tightening will distort cylinders, valve guides, and valve seats, Fig. 13-86. Follow manufacturer's recommendations.

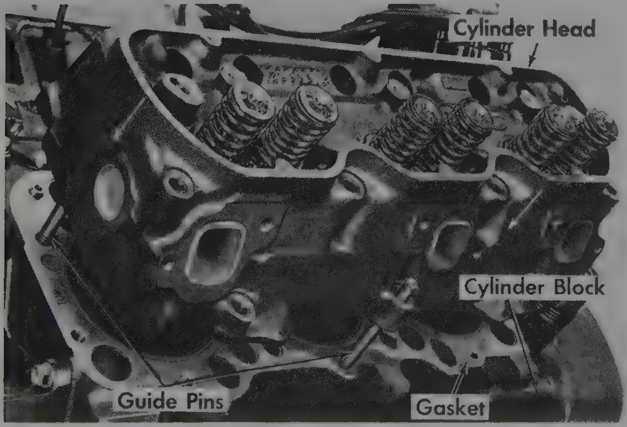


Fig. 13-85. Installing head using temporary long guide pins.

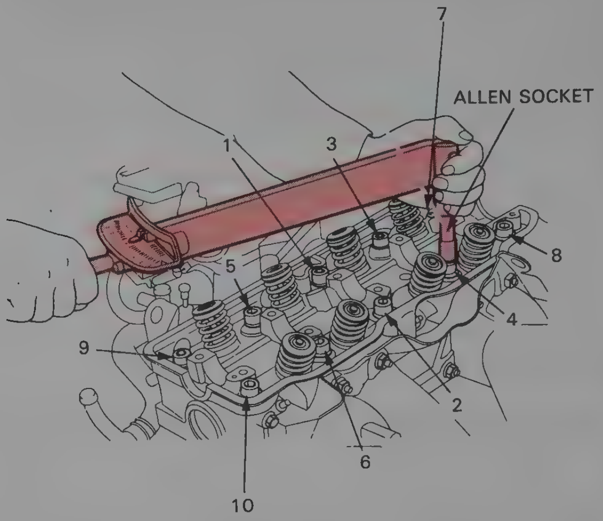


Fig. 13-86. Torque head bolts in sequence recommended by engine manufacturer. (Chrysler)

ROCKER ARM AND SHAFT SERVICE

Clean each rocker arm shaft. Pay special attention to the hollow center. Examine for signs of wear and scoring. Replace if necessary.

Check the condition of the rocker arm-to-shaft bearing surface. If bushings are used, wear can be corrected by rebushing and honing to size.

Excessive rocker arm-to-shaft clearance will permit a heavy flow of oil that could flood valve stems and increase oil consumption.

GRIND ROCKER ARM

The rocker arm valve stem end should be ground to a smooth even curve. Using a valve grinder, mount the

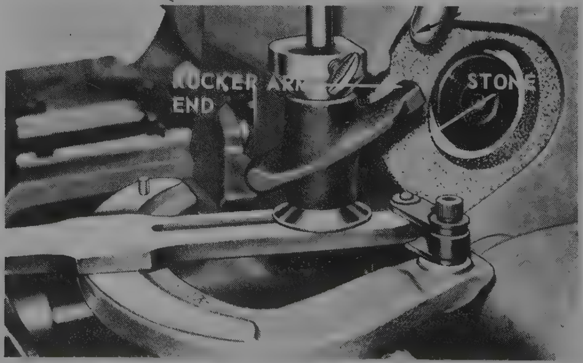


Fig. 13-87. Grinding rocker arm end. Remove no more stock than absolutely necessary. (Albertson-Sioux)

rocker arm so the end is parallel to the stone. Adjust the swivel attachment in such a way that the rocker arm end curve will be maintained. Dress the wheel. With one hand operating the swivel arm, and the other holding the rocker arm against the stone, wet grind until the surface is clean and true. Remove no more stock than necessary, Fig. 13-87.

Check the push rod end of the rocker. On nonadjustable versions, there will be a swivel pocket in the end. It must be smooth and free from galling. When an adjusting screw is provided, check the ball, Fig. 13-88.

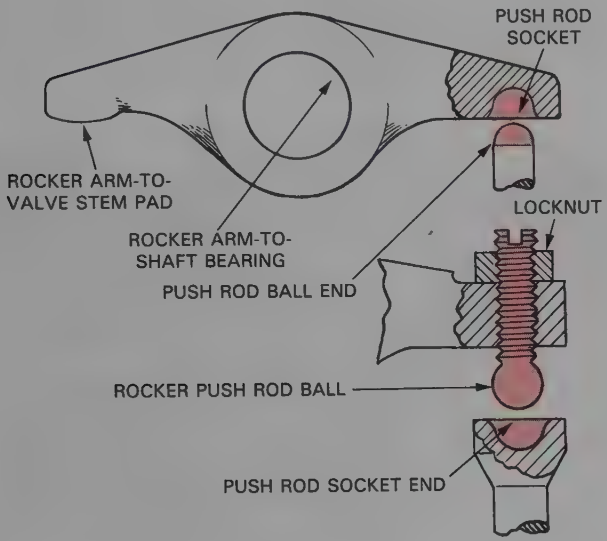

PUSH ROD SOCKET
ROCKER ARM-TO-VALVE STEM PAD
LOCKNUT
ROCKER ARM-TO-SHAFT BEARING
PUSH ROD BALL END
ROCKER PUSH ROD BALL
PUSH ROD SOCKET END

Fig. 13-88. Check rocker arm socket and ball. These must be smooth and free of excessive wear.

INSPECT PUSH RODS

Push rods should be straight and both ends must be smooth. If the push rod is designed to carry oil, be certain to clean the inside and blow dry.

Rod straightness can be checked with V-blocks and a dial indicator. Maximum allowable runout will vary. See specs and Fig. 13-89.

MECHANICAL LIFTERS OR TAPPETS

Clean lifter. Inspect push rod socket for signs of wear or galling. The lifter-to-camshaft surface should be smooth and free of cam wear, grooving, chipping, and galling. Lifters showing heavy camshaft wear or worn sockets should be replaced. If the wear is minor, the tappet may be resurfaced on the valve grinding machine. Lifter wear patterns are shown in Fig. 13-90.

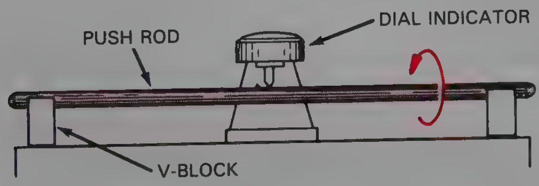

PUSH ROD
DIAL INDICATOR
V-BLOCK

Fig. 13-89. Checking push rod straightness with V-blocks and a dial indicator.

Tappet adjusting screws, such as shown in F, Fig. 13-90, may also be resurfaced providing the valve stem has not worn below the hardened portion.

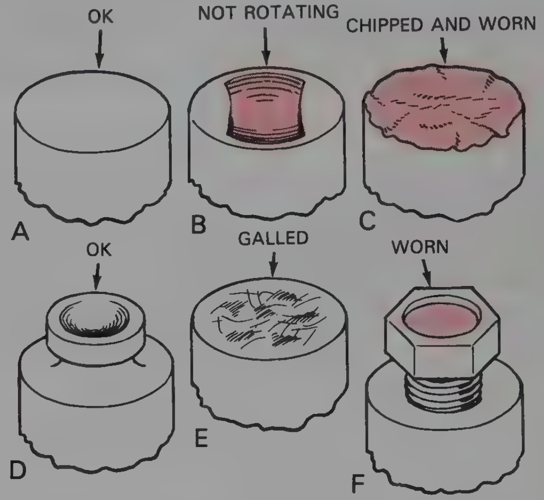

OK
NOT ROTATING
CHIPPED AND WORN
A
B
C
OK
GALLED
WORN
D
E
F

Fig. 13-90. Lifter wear patterns. A, B, C, E—Camshaft end of lifter. D—Push rod end of lifter. F—Tappet adjusting screw (L-Head engine).

GRINDING MECHANICAL LIFTERS

Dress the wheel surface. Secure the lifter in the V-block holder. While applying a stream of coolant to the lifter end, advance the lifter against the stone. Cuts should not exceed .002 in. (0.05 mm). Move the lifter back and forth over the stone surface. Do not remove any more stock than absolutely necessary. At the end

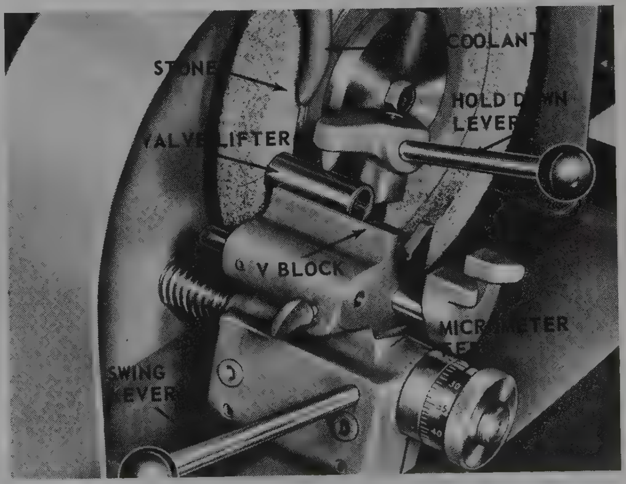

STONE
COOLANT
HOLD DOWN LEVER
VALVE LIFTER
V BLOCK
MICROMETER
SWING LEVER

Fig. 13-91. Resurfacing valve lifter end. (Van Norman)

of the last cut, continue to move the lifter back and forth until the cutting action stops. This will produce a smooth finish. If both ends of the lifter are adaptable to grinding, reverse and repeat the process, Fig. 13-91.

When lifter wear is pronounced, or galling and chipping are present, check the cam lobes carefully as they may also be damaged.

Oversize lifters may be used to correct lifter to bore clearance. When clearance exceeds .005-.006 in. (0.13-0.15 mm), replacement is necessary. The bores should be reamed to the exact oversize needed.

ROLLER LIFTERS

Some heavy duty engines (such as diesels) are equipped with roller lifters. They help reduce friction and aid in improved camshaft and lifter wear characteristics. They operate in the same manner as conventional hydraulic lifters with the exception of the roller, which engages the camshaft lobes. Instead of a sliding action, the lifter rolls on the cam surface. See Fig. 13-92.

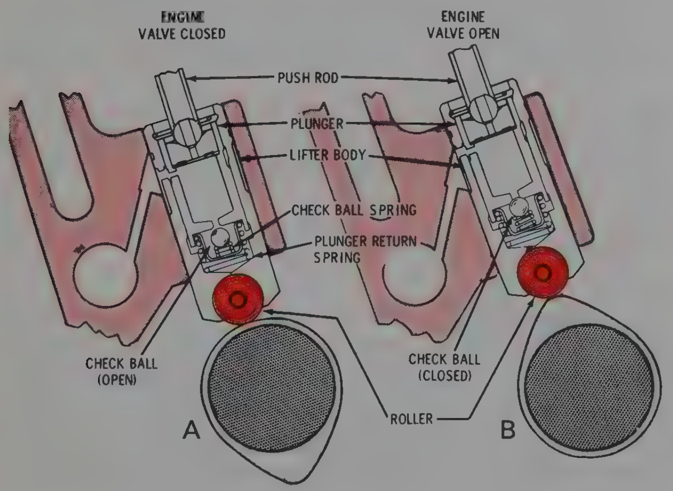


Fig. 13-92. Cross section of a hydraulic roller lifter. A—Valve in the closed position. B—Valve open. (Buick)

SERVICING ROLLER LIFTERS

When removing the lifters, be sure to keep them in proper order. If any part of the lifter needs replacing, discard the entire unit and replace with a new lifter assembly.

Disassembly and cleaning of these lifters is the same as with the nonroller type.

INSPECTION OF ROLLER LIFTERS

After the lifter has been disassembled and thoroughly cleaned, check for scoring, pitting, galling, varnish buildup, and evidence of other problems. Examine the roller next. It should be free of pits, roughness, and must rotate smoothly.

If pits or roughness are present on the roller, check the corresponding camshaft lobe for damage. If the same condition exists on the camshaft, then it must be replaced. If it is undamaged, just replace the lifter assembly.

SERVICING HYDRAULIC LIFTERS

The portion of the lifter body that protrudes below the guide bore is often coated with gum and varnish. This makes removal difficult unless a special tool is used to grasp the lifter. The tool is engaged and the lifter pulled upward with a twisting motion, Fig. 13-93.

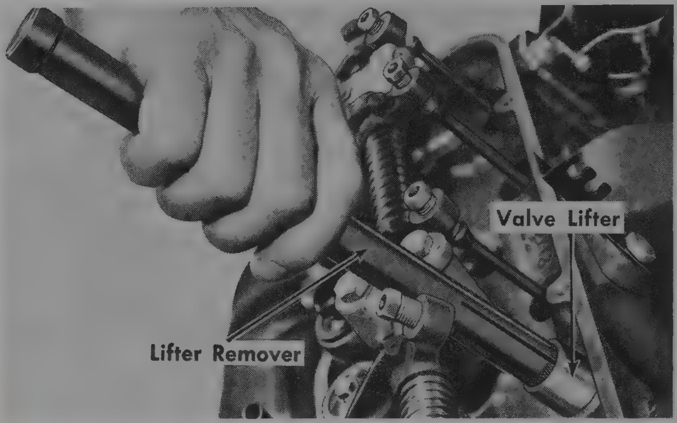


Fig. 13-93. Using a special puller to remove a hydraulic lifter. (G.M.C.)

KEEP LIFTERS IN ORDER

Each lifter should be placed in a marked holder so it may be returned to the guide bore from which it was removed. A block of wood with two rows of holes, each row representing one bank of lifters, will do.

DISASSEMBLING LIFTER

Place the lifter body, right side up, on a clean board. Using a push rod, depress the plunger and snap out the retaining ring, Fig. 13-94.

Release pressure on the plunger and guide it out of the lifter body. If the plunger sticks, and it often will, it may be removed with a tool designed for this purpose. One such tool operates by placing the lifter body in the tool and then striking the tool, plunger end down, against a block of wood.

KEEP PARTS OF LIFTERS TOGETHER

Lifter parts are made to extremely close tolerances (.0001 in. or 0.00254 mm) and the plunger is selectively

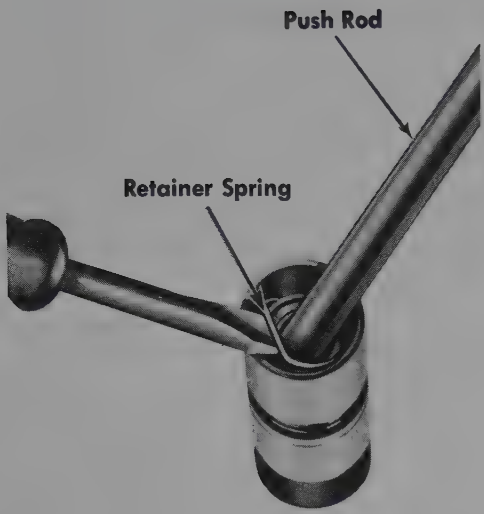


Fig. 13-94. Removing lifter plunger retaining ring. (Chevrolet)

fitted (several plungers tried until one fits perfectly) to the body. THE PLUNGER AND LIFTER BODY ARE NOT INTERCHANGEABLE and must be kept together. Fig. 13-95 shows a disassembled lifter. The check valve retainer, spring, and valve are still in place on the plunger.

As each lifter is disassembled, place the parts in individual, MARKED trays.

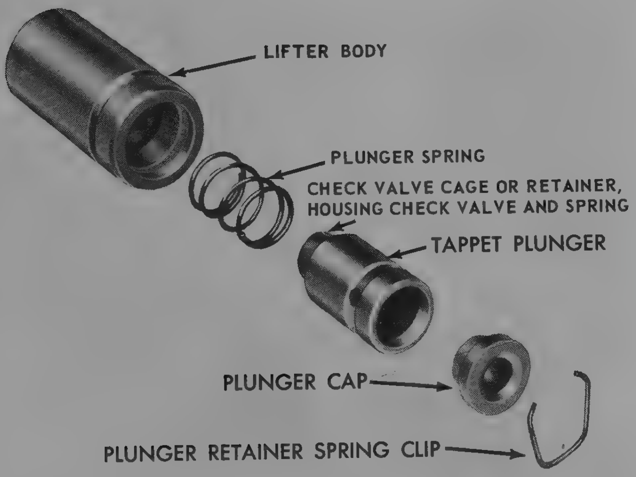

LIFTER BODY
PLUNGER SPRING
CHECK VALVE CAGE OR RETAINER, HOUSING CHECK VALVE AND SPRING
TAPPET PLUNGER
PLUNGER CAP
PLUNGER RETAINER SPRING CLIP

Fig. 13-95. Typical hydraulic lifter partially disassembled. (Plymouth)

CLEANING LIFTERS

A special cleaning station, such as shown in Fig. 13-96, is desirable. Note the trays in which lifter parts are kept together. The tray on the left contains a special cleaning solvent designed to dissolve gum and varnish. The central tray contains clean kerosene for rinsing. The small tray contains clean kerosene for a FINAL rinse. A clean work area is also provided, Fig. 13-96.

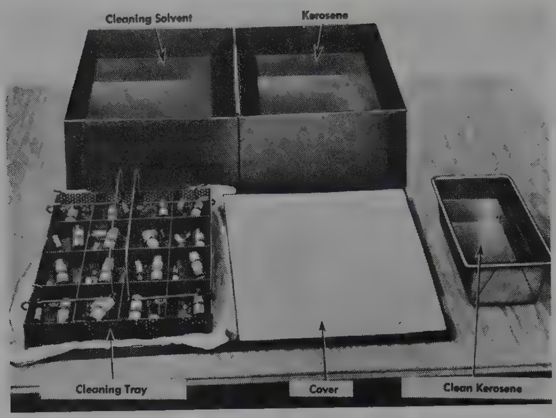


Fig. 13-96. A good setup for cleaning hydraulic valve lifters.

Due to the close working tolerances, lifters must be THOROUGHLY CLEANED and assembled in a SPOTLESS CONDITION. The SLIGHTEST TRACE of grit, dust, or lint will cause faulty operation.

After all lifters are dismantled, rinse each group of parts in clean kerosene. DO NOT USE THE KEROSENE IN THE TRAYS. This first rinse is merely to remove most of the oil and sludge so the useful life of the special cleaning solvent will be prolonged.

SOAK IN SOLVENT

Following the initial rinse, place the tray with compartments into the cleaning solvent. Lay plungers and lifter bodies on their sides so the solvent will enter. Allow them to soak for about one hour. Exact soaking time will depend on the type of solvent used, how often used, and condition of lifters. KEEP HANDS OUT OF CLEANING SOLUTION AND AVOID SPLASHING. IT IS WISE TO USE RUBBER GLOVES WHILE CLEANING LIFTERS.

When the soak cycle is completed, elevate the tray. After tipping from side to side to empty parts of solvent, suspend the tray over the solution until the excess solvent has dripped off.

RINSE IN KEROSENE

When thoroughly drained, place tray in the pan of initial rinse kerosene. Agitate the tray several times by lifting and lowering. Remove and allow to drain. This rinse will remove the cleaning solvent and a great deal of the loosened deposits.

Wipe all lifter surfaces with a clean, lint-free cloth. Use a firm wiping action to remove all remaining gum. A soft bristle brush should be used for the inside of the lifter and plunger bodies. When all lifters have been cleaned, place the tray in the center container of kerosene. Agitate, remove, and allow to drain. Blow all parts dry.

INSPECT LIFTER PARTS

(PLUNGER): Use a magnifying glass to inspect plunger check valve seat for nicks, scratches, and wear. Inspect outer plunger body for signs of galling. Any scratches on either the check seat or plunger body that can be felt with the fingernail are cause for rejection. Ignore the slight edge that may occur where the plunger extends beyond the inner working surface of the lifter body. However, if this edge is quite sharp, the plunger must be considered defective.

(LIFTER BODY): Check the lifter body inner and outer surfaces. They must be smooth and free of scoring. The lifter-to-cam lobe surface must also be smooth and free of galling, chipping, and excessive wear. A round wear pattern (lifter was rotating) or a square wear pattern (lifter not rotating) as long as the pattern is smooth and free of wear, is acceptable.

The outer portion of the lifter body that contacts the lifter guide bore will usually show a distinct wear pattern caused by cam lobe side thrust. It too, unless scored or pronounced, can be considered acceptable.

(PUSH ROD SEAT): If the push rod seat is scored or badly worn, replace it.

(CHECK BALL OR VALVE DISC): Examine the check ball with the magnifying glass. Any nicks, dents, or scratches will render it useless.

(BALL RETAINER): The ball retainer will show a bright spot where it contacts the check ball. This is normal. A pounded area or any cracks will be cause for rejection.

(SPRINGS): Inspect both plunger and check valve springs for signs of distortion or other damage. Replace if necessary.

(PLUNGER RETAINER RING): Discard any retainer rings that are bent out of shape.

REPLACING PARTS

Some garages replace, when required, the push rod seat, retainer ring, ball retainer, check ball or disc, and the springs.

Other garages, when any part shows damage, discard the entire assembly. This school of practice employs the argument (and it is a good one) that the cost of new lifters is small compared to that of the possible comeback from some premature lifter failure.

There are also garages that will, when there is considerable mileage on the engine, not even clean and inspect the lifters. They are automatically discarded in favor of new ones. Disassembly and cleaning plus inspection, reassembly, and testing take some time. If the cost of this labor is deducted from the price of new lifters plus the increased reliability factor, there is much to be said for replacement.

INSPECT AND ASSEMBLE ONE AT A TIME

After all the parts of one lifter have been inspected and where required, replaced, they should be rinsed in the central tray of kerosene, blown dry, and thoroughly rinsed in the small pan of kerosene. Each part, as it is assembled, must be put through this sequence. One entire lifter should be inspected and assembled before going on to the next.

LIFTER ASSEMBLY

With the plunger held vertically, push rod seat in place, check valve seat up, place the check ball or check disc on the seat. Set the check valve spring over the valve. Place the valve retainer over the spring and snap it down into plunger recess. The plunger spring is then placed over the ball retainer and the lifter body lowered down over the plunger.

Turn the lifter body right side up. Depress the push rod seat and install the retainer ring. Wrap assembly in clean, slick paper, and proceed to the next lifter. ALL LIFTER PARTS SHOULD BE ASSEMBLED WET WITH RINSE KEROSENE. DO NOT WIPE OR BLOW DRY.

Figs. 13-97 and 13-98 illustrate two typical hydraulic lifter assemblies. Note respective position of all parts.

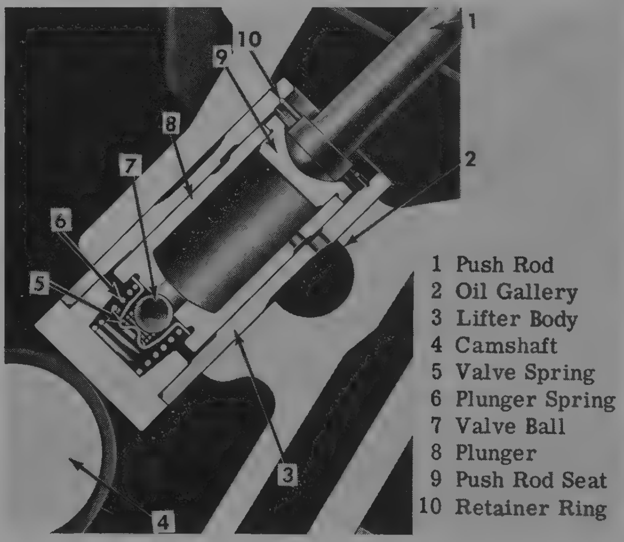
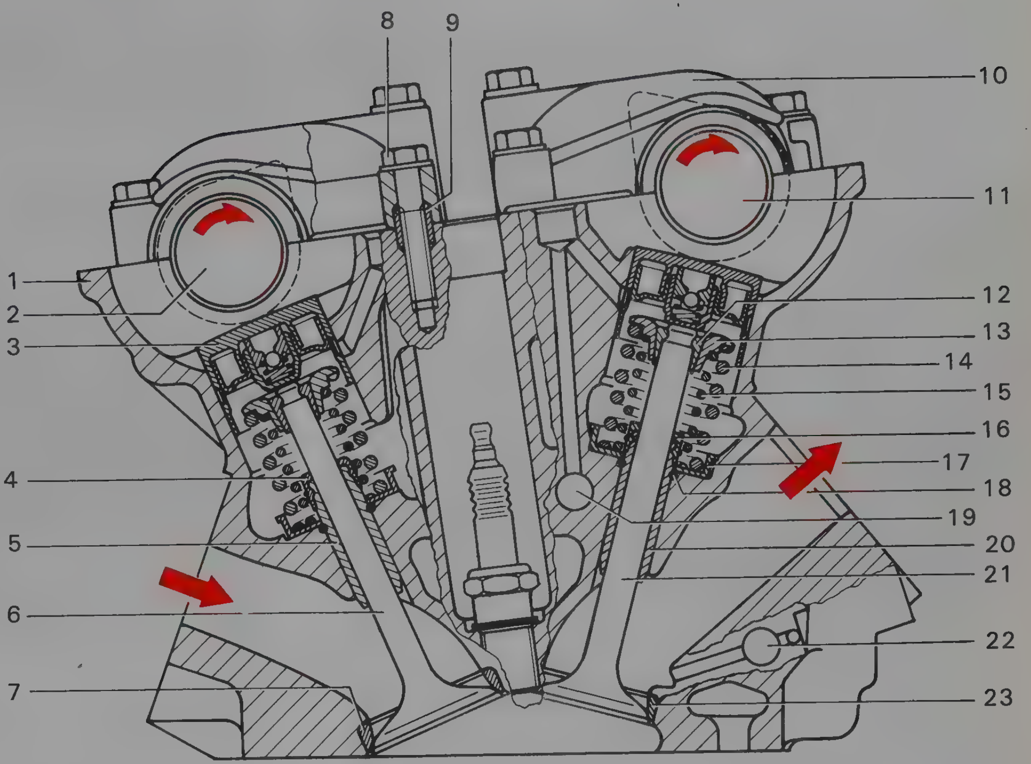


Fig. 13-97. Hydraulic lifter utilizing a ball check valve.

CHECKING LEAKDOWN RATE

Each lifter must possess the correct leakdown rate characteristic. Leakdown rate is the length of time it takes for a specified weight to move the plunger (lifter filled with test fluid) from the top to the bottom. This is usually a specified distance.



1 Cylinder head
2 Intake camshaft
3 Valve tappets with hydraulic valve clearance compensators
4 Intake valve stem seal
5 Intake valve guide
6 Intake valve
7 Intake valve seat
8 Bolt
9 Locating sleeve
10 Bearing support
11 Exhaust camshaft
12 Valve keeper
13 Upper valve spring retainer
14 Outer valve spring
15 Inner valve spring
16 Exhaust valve stem seal
17 Lower valve spring retainer
18 Retaining ring
19 Oil gallery
20 Exhaust valve guide
21 Exhaust valve
22 Air injection duct
23 Exhaust valve seat

Fig. 13-98. Overhead camshaft assembly using hydraulic valve lifters. (Mercedes-Benz)

If a test tool similar to that in Fig. 13-99 is available, test the leakdown rate as follows: raise the weight arm and ram. Place the lifter in the special sleeve inside the test cup. The cup must have sufficient CLEAN test fluid to completely cover the lifter.

Lower the ram against the push rod seat. Swing the weight arm down on the ram and depress lifter plunger. Work the weight arm up and down to completely fill the lifter with fluid. After a number of strokes you will notice a firm resistance on the compression stroke. Give the arm 8 or 10 additional fast pumps to make certain all the air is expelled.

Raise the weight arm and allow the plunger to rise against the stop ring. Using a watch with a second hand, place the weight on the ram. The instant the indicator needle begins to move, observe the time. Give the cup lever a complete turn every two seconds while the plunger is being depressed. When the indicator needle has traveled the prescribed distance, check to see how many seconds have elapsed. See manufacturers' specs for acceptable leakdown rate, Fig. 13-99.

Another leakdown tester is shown in Fig. 13-100. The push rod seat is removed and the lifter is submerged in clean kerosene. Depress the check valve with a clean,

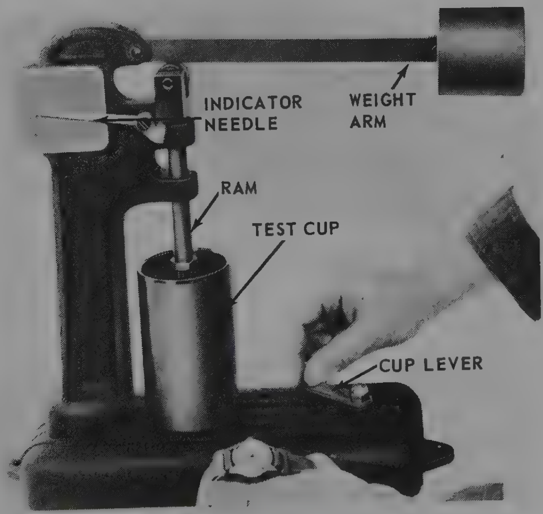


Fig. 13-99. Testing leakdown rate. (Chevrolet)

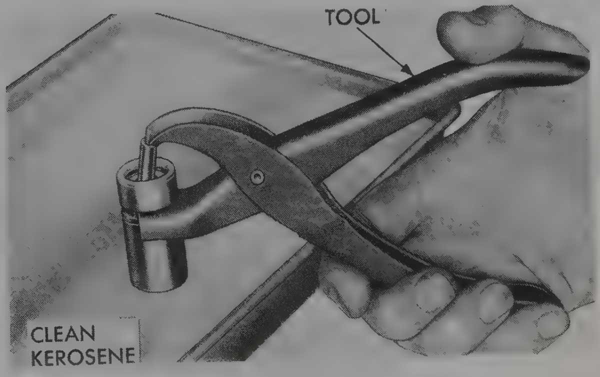


Fig. 13-100. Testing leakdown rate with special test pliers. (Dodge)

soft rod. This will allow the bottom area to fill. When completely filled, remove and install push rod seat. The test pliers are engaged as shown and the handles squeezed. The plunger should slowly move downward. If travel is rapid, disassemble, clean, check, and reassemble. Make sure the lifter is completely filled with kerosene prior to testing, Fig. 13-100.

LIFTER INSTALLATION

Lifters may be filled with 10W engine oil by removing the push rod seat and draining out the kerosene. Fill the plunger body with CLEAN oil. Jiggle the check valve open to allow oil to fill the lower compartment. When this is full, fill the plunger body and replace push rod seat. Lubricate the outside of the lifter body and lifter guide bore. Rub a small amount of Lubriplate or rear axle lubricant on both the cam lobe and push rod ends of the lifter. Install the lifter in the hole from which it was removed.

When lifters have been installed without filling with oil, the engine rpm upon starting, should not exceed a fast idle until all lifters are pumped up (filled with oil).

ROCKER ARM AND SHAFT ASSEMBLY AND INSTALLATION

The rocker arms, spacers, springs, and related parts, following cleaning and inspection, should be lubricated and assembled on the shaft. Be very careful to install the arms in the correct locations and facing in the right direction. They must also be correctly placed in relation to the front of the shaft. Fig. 13-101 shows the installation of rocker arms on a shaft that slides into struts in the head.

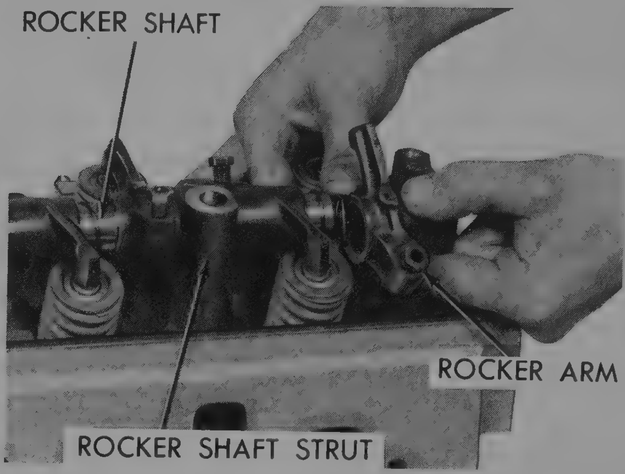


Fig. 13-101. Installing rocker arms. Note that this shaft slides through integral brackets or struts. (Chrysler)

The assembled rocker arms and springs are shown in Fig. 13-102. Note the different angles on the intake and exhaust rockers. The shaft is held in position by the lock plug.

A different style of rocker arm assembly is pictured in Fig. 13-103. Note the flat on the front end of the rocker shaft.

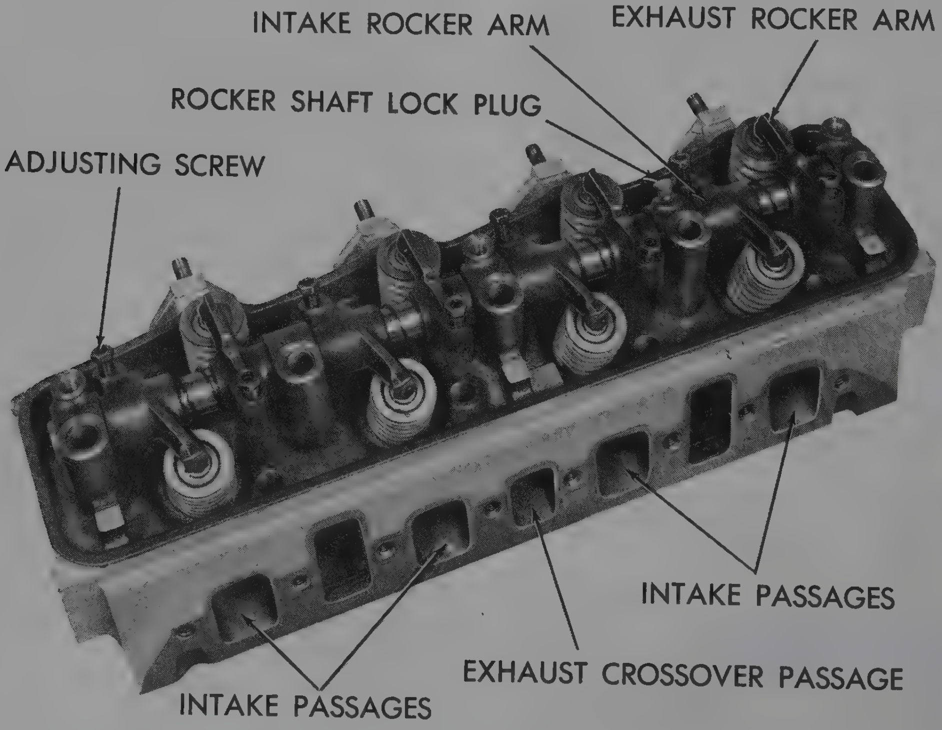


Fig. 13-102. Rocker arm assembly completed.

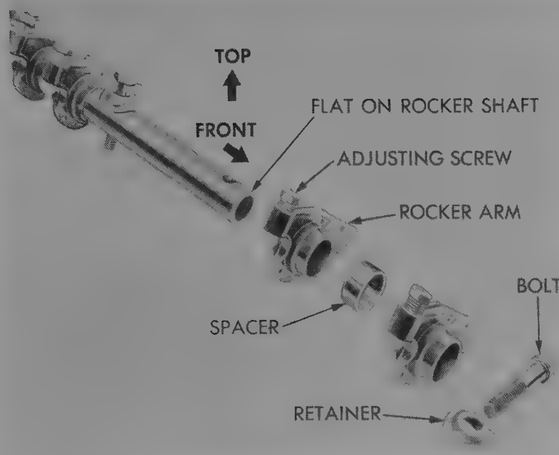

TOP
FRONT
FLAT ON ROCKER SHAFT
ADJUSTING SCREW
ROCKER ARM
BOLT
SPACER
RETAINER

Fig. 13-103. Another style rocker arm assembly. Note use of spacers between rockers.

ROCKER ARM SHAFT POSITIONING

The hollow rocker shaft carries a supply of oil to the rockers. Therefore, it is important that the support bracket, designed to transfer oil from the cylinder head to the shaft, is properly located. Fig. 13-104 shows two methods of carrying oil via support brackets.

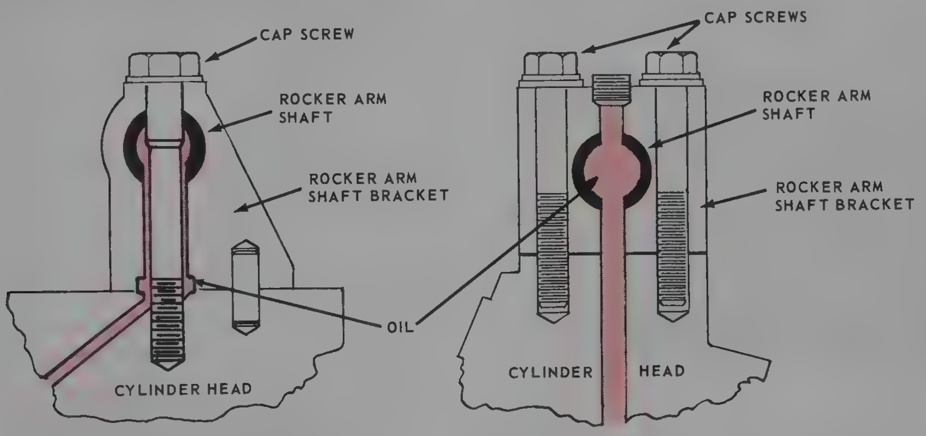

CAP SCREW
ROCKER ARM SHAFT
ROCKER ARM SHAFT BRACKET
OIL
CYLINDER HEAD
CAP SCREWS
ROCKER ARM SHAFT
ROCKER ARM SHAFT BRACKET
CYLINDER HEAD

Fig. 13-104. Two methods of supplying oil to rocker shaft via support brackets.

To assure that the oil supply opening in the shaft indexes with the correct bracket, make sure that the marked end (flat or notch) faces the specified end of the engine. The notch or flat must also be positioned (up, down, to the side) as recommended. Fig. 13-105 illustrates the marked ends and the various positions for these particular assemblies.

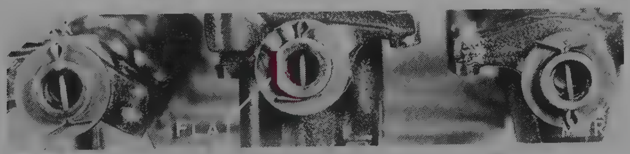


Fig. 13-105. Rocker arm shaft positioning marks.

The individual rocker oil passages are generally positioned so they face toward the head. This provides positive lubrication for the heavily stressed lower rocker bearing area. It also permits less oil flow due to the reduced clearance between the rocker and the bottom of the shaft. If the oil passages were turned upward, an excessive amount of oil would be passed. This would overlubricate the valves with resultant heavy oil consumption. Fig. 13-106 illustrates the usual positioning of these oil passages. Note that less clearance exists between the bottom of the shaft and the rocker arm.

The individual ball stud rocker arms are lubricated by a metered flow of oil delivered through hollow push rods.

Shaft mounted rocker arms are drilled in various ways to facilitate the flow of oil to both valve stem and push rod ends. Fig. 13-107 shows one method.

ROCKER ARM ASSEMBLY INSTALLATION

On some engines, the push rods are installed before the rocker assembly. On others the rocker assembly is installed first. The push rods are placed in the lifters

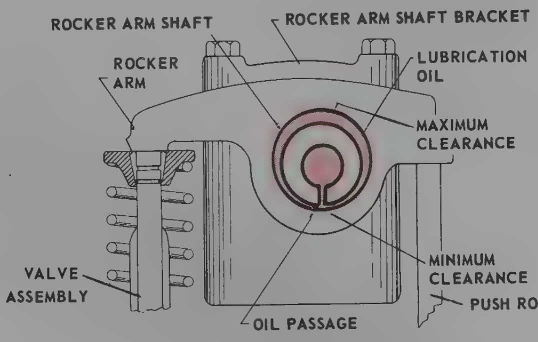

ROCKER ARM SHAFT
ROCKER ARM SHAFT BRACKET
ROCKER ARM
LUBRICATION OIL
MAXIMUM CLEARANCE
MINIMUM CLEARANCE
PUSH ROD
VALVE ASSEMBLY
OIL PASSAGE

Fig. 13-106. Rocker arm oil passages in shaft generally face toward head.

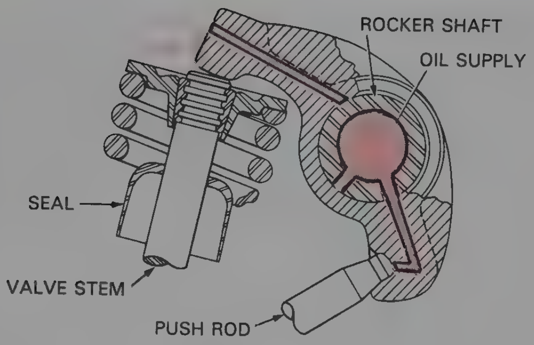


Fig. 13-107. Rocker arm drilled for oil. (Buick)

and the valve spring compressed. This tips the rocker high enough to place the push rod under the rocker ball end.

The engine in Fig. 13-108 has the push rods installed. Note the special installing rod that holds the push rod upper ends in alignment. When the rocker assembly is installed, they will all line up.

A small amount of Lubriplate, or some other suitable lubricant, should be applied to each end of the push rod before installing.

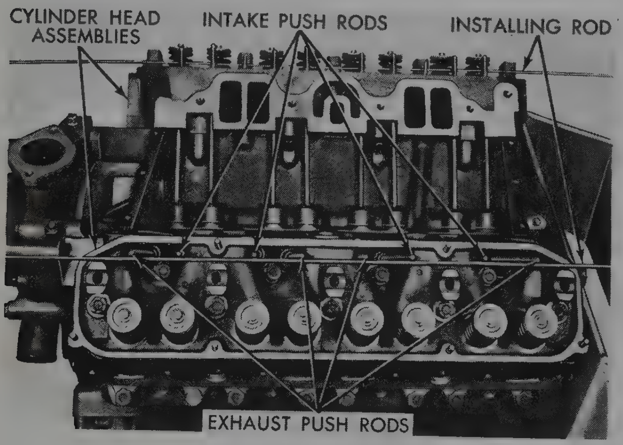


Fig. 13-108. Push rods held in position for rocker arm assembly installation with special installing rods. (Plymouth)

TIGHTEN ROCKER SHAFT BRACKETS EVENLY AND SLOWLY

Lubricate bracket cap screws and run up finger tight. Give each bracket bolt, one after the other, a couple of turns. Proceed slowly. If the hydraulic lifters are filled with oil, and the shaft assembly is drawn rapidly against the head, bent push rods, bulged lifters, warped valve stems, and sprung rockers can result. By drawing the assembly down slowly, the lifters will have time to leak down without undue strain on the various parts.

The rocker adjusting screws, where used, should be backed off before tightening the assembly. This applies to conventional lifter setups too. When the brackets are snugged against the head, torque to specs, Fig. 13-109.

If an oil overflow line is incorporated in the rocker assembly, make sure it is installed properly.

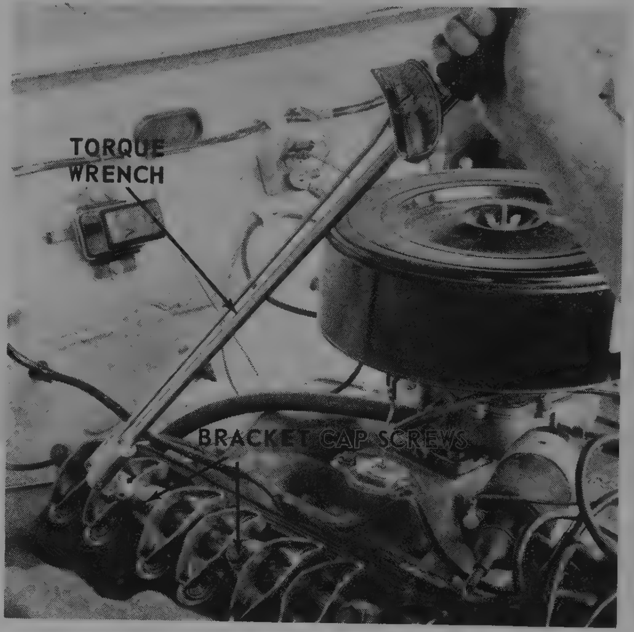


Fig. 13-109. Torquing rocker arm shaft bracket cap screws. (Sturtevant)

ADJUSTING VALVE LASH OR CLEARANCE (HYDRAULIC LIFTERS)

Hydraulic lifters are used primarily to eliminate the need for lash or clearance between the end of the valve stem and the rocker arm. When the parts heat up and elongate, the lifter will leak down. Any shortening will cause the lifter to pump up. In this way, zero clearance is constantly maintained.

Unlike conventional lifters that need periodic adjustments, once set, the hydraulic lifter requires no further adjustment.

Some engines have no provision for adjustment on the rocker arms. Valve stem length above the head, head gasket thickness, push rod and rocker wear all become critical on an installation of this type. However, push rods are available in different lengths to compensate for small changes needed.

The object in adjusting hydraulic lifters is to place the lifter plunger somewhere near the center of its stroke. This will allow changes, as needed, in both directions. If the plunger is forced to the bottom, it will act as a solid lifter. If allowed to remain at the top, it cannot compensate for wear and temperature contractions.

LIFTER MUST BE ON CAM LOBE BASE CIRCLE

Rotate the engine until the cam lobe nose faces directly away from the lifter. The lifter will then rest on the base circle.

There are several ways of determining when the lobe is in this position. On some engines, such as the overhead camshaft type, the lobe is visible. If the engine is in the car and the ignition is properly timed, the engine can be slowly turned over until the plug lead to the cylinder fires. At this instant, both valves are closed and the lobes are in the proper position for lash setting.

Slowly crank the engine until a particular valve is fully opened. Then give the CRANKSHAFT exactly one full turn (mark damper with chalk). The cam lobe will be turned one-half revolution, thus placing the lobe nose opposite the lifter.

When a piston is brought to TDC (top dead center) on the compression stroke (both valves closed) the lobes are in the correct position for that cylinder.

Another technique involves dividing the damper, with chalk marks, into two 180 deg. sections (four cylinder), into three 120 deg. sections (six cylinder), or four 90 deg. sections (V-8). One of the marks is on the timing notch, and the others are related in degrees to this mark. By cranking the engine, in various sequences, until the marks index with the timing pointer, it is possible to set certain valves and reduce the amount of cranking required. Look at Fig. 13-110.

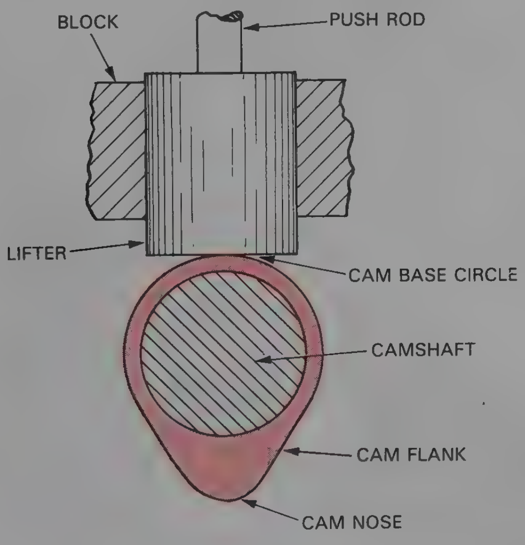


Fig. 13-110. To set valve lash or clearance, lifter must rest on cam base circle.

LIFTER PLUNGER MUST BE AT TOP OF TRAVEL

The rocker arm adjustment should be loosened so the lifter plunger travels to the top of its stroke. At this point, the push rod can be "jiggled" sideways and up and down. See Fig. 13-111.

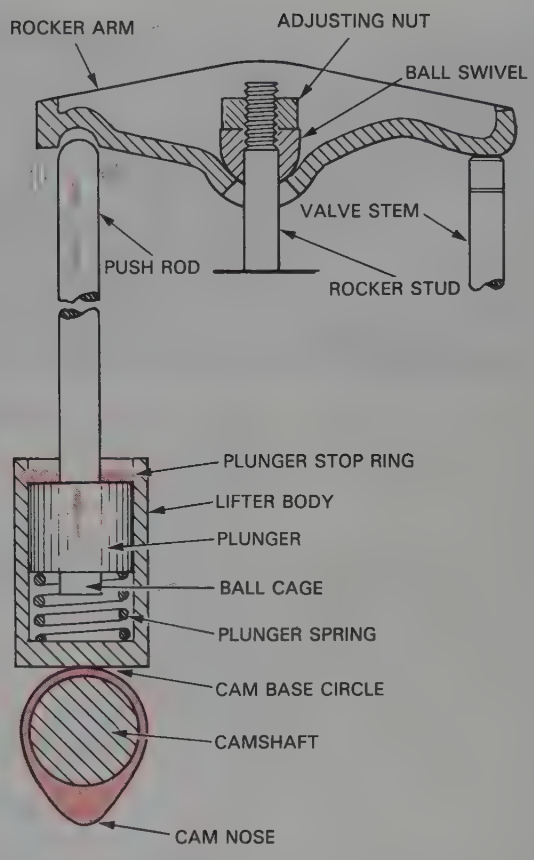


Fig. 13-111. Hydraulic lifter plunger against stop ring, rocker arm backed off until push rod shake is evident.

Grasp the push rod concerned with the thumb and forefingers. While gently shaking it sideways, slowly tighten the rocker arm adjustment. As the rocker arm push rod end moves downward, the amount of shake will be reduced. Stop at the instant all play or shake is gone. At this point, no lash is present between valve stem and rocker, or rocker and push rod.

Following manufacturer's specs, give the rocker arm adjustment an additional number of turns (1 1/2 typical). This will force the plunger down to the midpoint of its stroke. Repeat this process on all rockers. Fig. 13-112 shows a mechanic shaking the push rod while drawing rocker downward to the point all clearance is gone. Where adjustment is not provided, compress lifter and check push rod to rocker clearance against specs. Install longer or shorter push rod if necessary.

ADJUSTING VALVE LASH (MECHANICAL LIFTERS)

A certain amount of lash or clearance between the valve stem and the rocker arm is a MUST when mechanical lifters are employed. The exact amount will

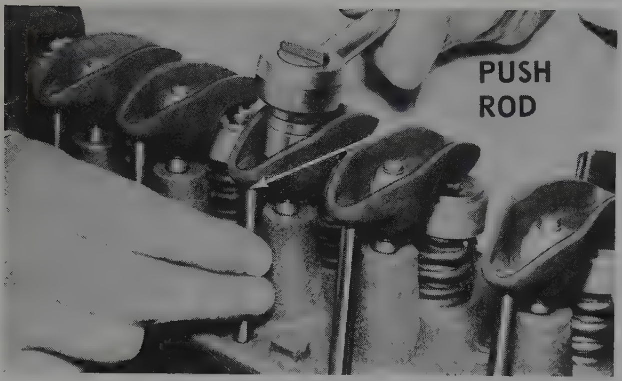


Fig. 13-112. Removing push rod shake prior to final adjustment of hydraulic lifters. (G.M.C.)

vary from engine to engine, depending on the use, design, and construction. Always use the amount specified by the manufacturer.

Excessive tappet clearance will cause noisy operation, late valve opening and early closing, lowered valve lift, excessive wear, and possible valve breakage. Insufficient clearance will cause early opening, higher lift, late closing, and valve burning.

As with the hydraulic lifter, the mechanical lifter must rest on the cam base circle. The rocker arm is carefully adjusted so that the correct clearance, as determined by feeler gauges or a dial indicator, exists between valve stem and rocker arm.

A feeler gauge of the exact thickness or a stepped GO-NO GO blade (GO = .001 in. or 0.025 mm below specs) (NO GO = .001 in. or 0.025 mm above specs) should pass between rocker and valve stem (hold push rod end down) with a slight drag, Fig. 13-113.

Fig. 13-114 illustrates valve clearance being checked with a dial indicator. This device gives highly accurate settings.

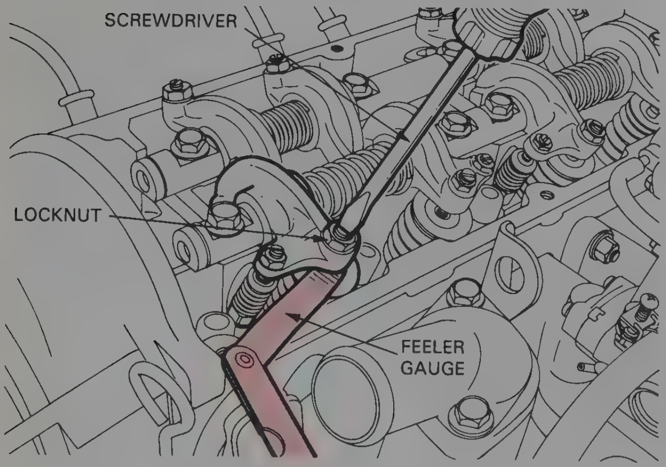


Fig. 13-113. Adjusting valve clearance using a feeler gauge. When set, tighten locknut and recheck. (Chrysler)

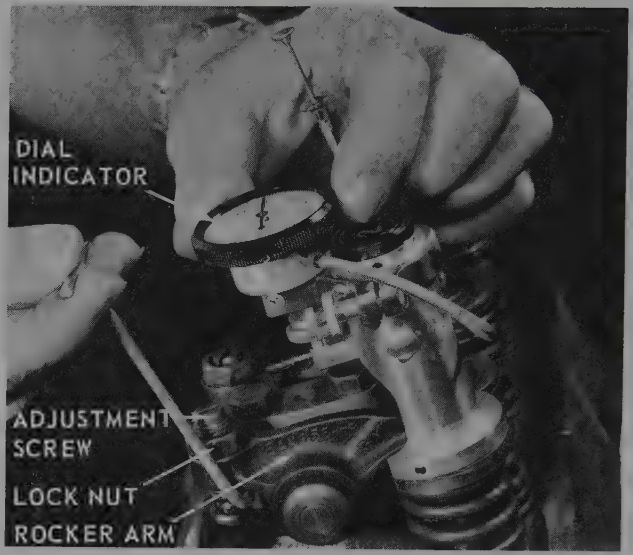


Fig. 13-114. Using a special dial indicator setup to check tappet clearance. Adjustment screws have locknuts. (P and G Co.)

COLD AND HOT CLEARANCE SETTINGS (MECHANICAL LIFTERS)

When an engine is reassembled, an initial or COLD setting of the valve clearance is necessary. For a final

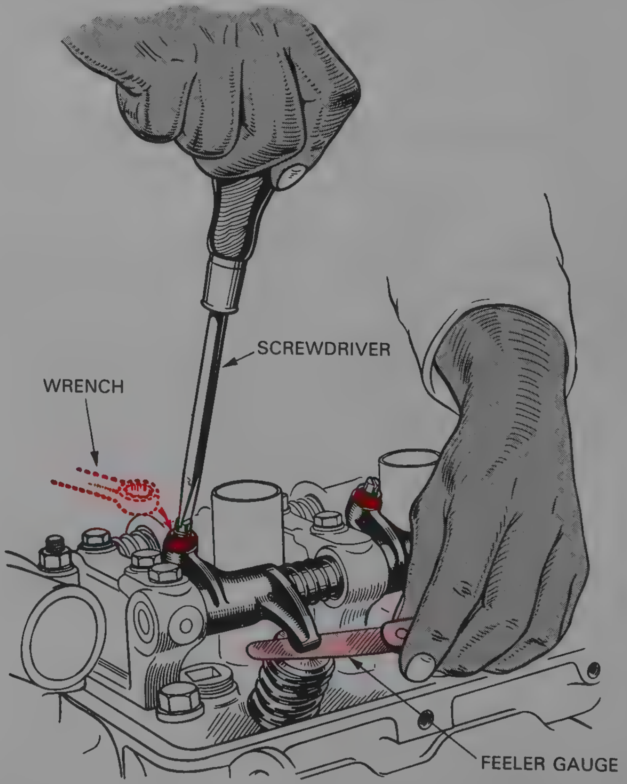


Fig. 13-115. Adjusting valve clearance. Note use of locknuts on adjusting screws. Some engines use self-locking screws or nuts. The screwdriver engages adjustment screw while wrench is used to tighten locknut. (British-Leyland)

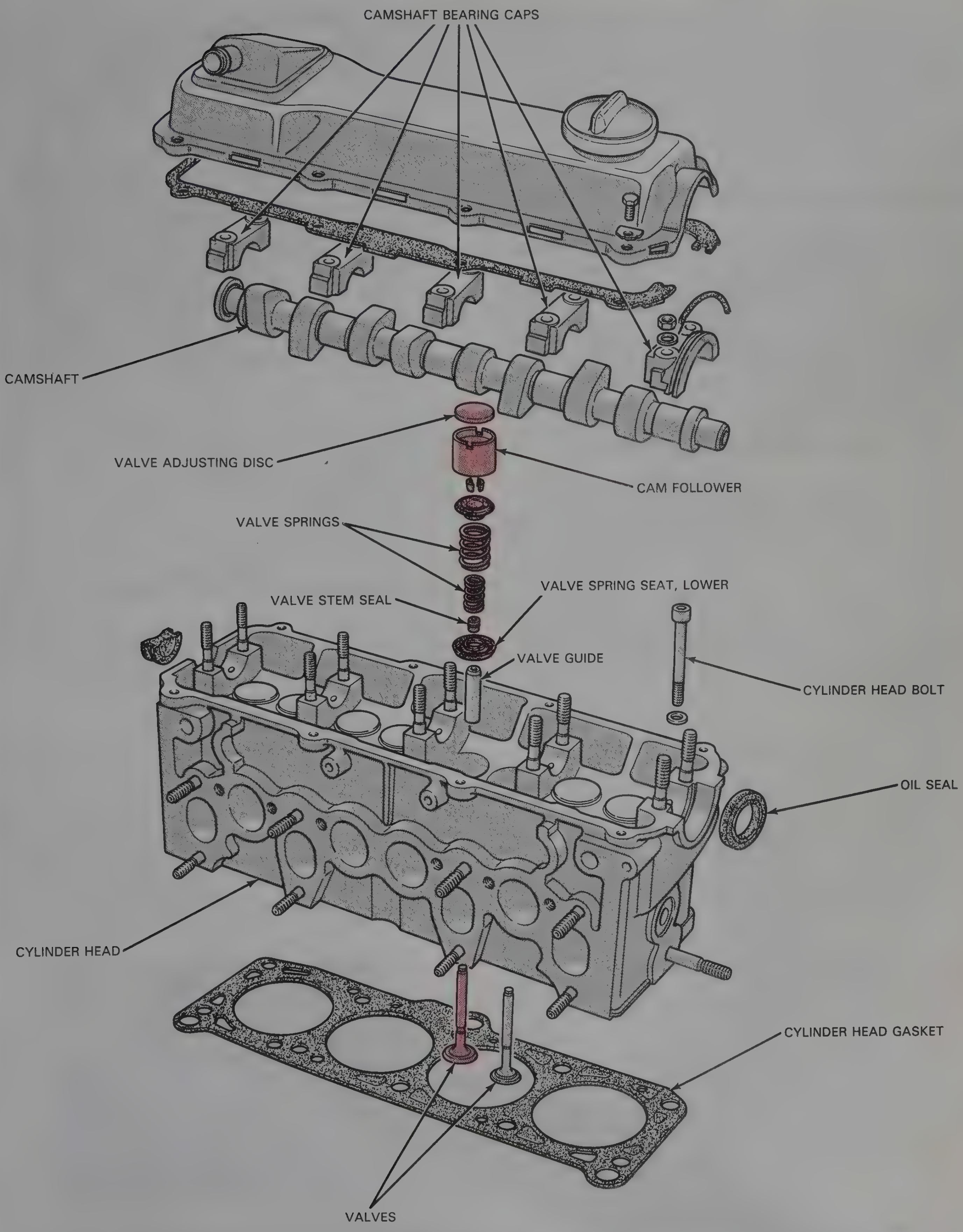

CAMSHAFT BEARING CAPS
CAMSHAFT
VALVE ADJUSTING DISC
CAM FOLLOWER
VALVE SPRINGS
VALVE STEM SEAL
VALVE SPRING SEAT, LOWER
VALVE GUIDE
CYLINDER HEAD BOLT
OIL SEAL
CYLINDER HEAD
CYLINDER HEAD GASKET
VALVES

Fig. 13-116. One direct-acting, overhead camshaft setup. Cam lobe acts directly (no rocker arm) on valve stem via cam follower. Proper valve clearance is set by selecting correct thickness valve adjusting disc. (Plymouth)

HOT clearance setting, the engine must be up to normal operating temperature (oil as well as water temperature). This will require about thirty minutes of engine operation.

ACCURATE VALVE CLEARANCE IS IMPORTANT. Make certain the engine is hot and that clearance settings are exact.

ROCKER ARM ADJUSTING SCREWS

Some rocker arm adjusting screws are self-locking. A specified amount of torque must be applied to move them. If the "breakaway" torque is below accepted limits, change the screw or the nut.

If a locknut adjusting screw is used, loosen the nut. Adjust the screw. While holding the screw, firmly tighten the nut. After tightening, recheck valve clearance, Fig. 13-115.

DIRECT ACTING OVERHEAD CAMSHAFT

Some engines employ overhead camshaft setups in which the cam lobes act directly on the valves through a cam follower. No rocker arms are needed. Fig. 13-116 shows an exploded view of an engine with such an arrangement.

Valve clearance is set by an adjusting disc either resting on the top of the follower, Fig. 13-116, or placed between the follower and the valve stem, Fig. 13-117. Various disc thicknesses are available to alter clearance as needed.

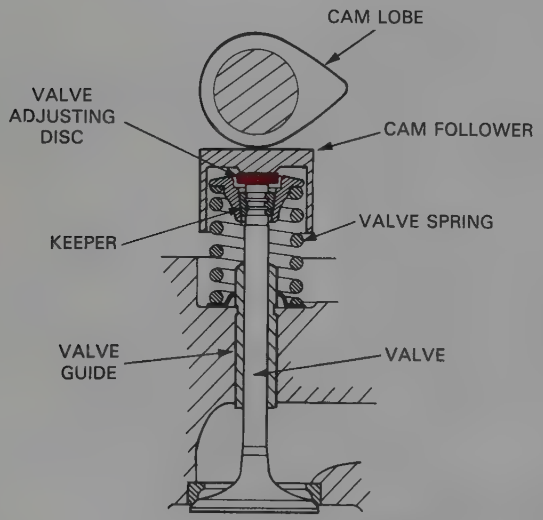


Fig. 13-117. Another direct acting overhead camshaft arrangement. This assembly places adjusting disc between cam follower and valve stem. (Saab)

Another setup uses a tapered adjusting screw by which clearance can be set. The taper produces a wedging effect that alters clearance when the screw is turned. See Fig. 13-118.

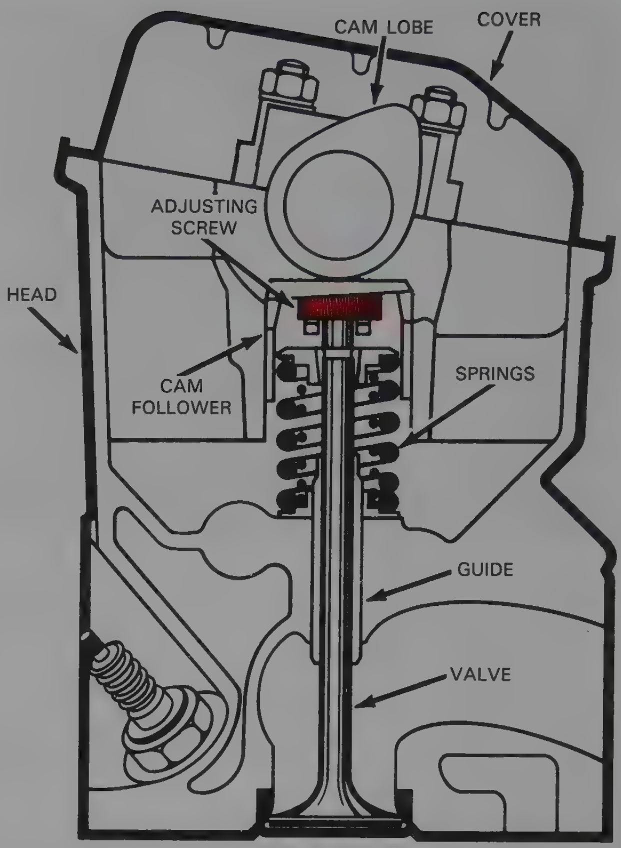


Fig. 13-118. The valve clearance for this overhead camshaft engine is adjusted by turning a tapered adjusting screw. This will increase or decrease distance between cam lobe and follower. (American Motors)

CHANGING VALVE SPRING—HEAD ON ENGINE

Bring the piston to TDC on the compression stroke (both valves closed) or remove the rocker arms for that cylinder. Remove the spark plug and insert an air hose adapter. Admit full air pressure to the cylinder. With the rocker arm out of the way, the spring may be compressed and the keepers removed. A new spring or a

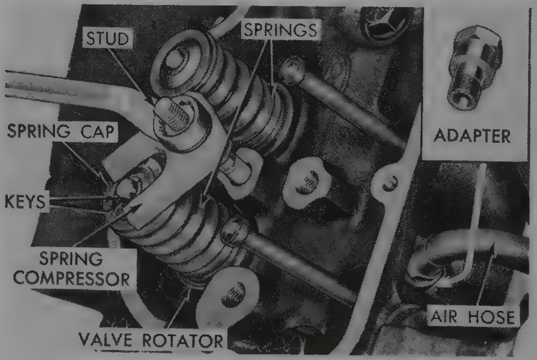


Fig. 13-119. Removing valve spring assembly with head on engine. Note use of air hose adapter in spark plug hole. (G.M.C.)

valve guide seal may be installed. KEEP AIR PRESSURE TO THE CYLINDER UNTIL THE VALVE SPRING IS REPLACED AND THE KEEPERS INSTALLED, Fig. 13-119.

SUMMARY

Never remove a cylinder head when hot. Remove rocker arm assembly brackets evenly, a couple of turns on one, the same on the others. Loosen head bolts a little at a time in the reverse order of the tightening sequence.

Keep lifters, push rods, valves, and rocker arms in order so that they may be replaced in the same location.

Head, valves, guides, and other parts must be thoroughly cleaned. Do not scratch aluminum head surfaces.

Reface all valves. Reject any that will not clean up and those with insufficient margin. An interference angle may be used. Dress stones. Smooth and chamfer stem end. Stem must not be worn beyond limits.

Check valve stem-to-guide clearance. If excessive, replace guides or ream for an oversize stem. When replacing guides, be certain to get the proper guide, right side up, in the correct hole. Drive in to the specified distance. Some guides require reaming after installation.

To prevent excessive oil consumption, seals are often used on the guides, and on the stem of both intake and exhaust valves.

Cracked or burned seats can be repaired by installing a valve seat insert. Grind valve seat, at correct angle, until cleaned up. Narrow seat to specified width by using a 15-30 deg. stone on the top and, in some cases, a 60-70 deg. stone one the bottom. Test seat for concentricity. Keep stones properly dressed. Remove no more metal than necessary.

Replace broken, loose, or damaged rocker arm studs. If loose, ream and install an oversize stud.

Check valve springs for squareness, tension, rust, or nicks. Replace any that show the SLIGHTEST defect.

Using an accurate straightedge, check cylinder head for warpage.

Lubricate and install valves. Check stem height above head. Install springs, closed coil end against head. Check installed spring height. Add insert under spring against head, if needed. Check stem seal with suction cup.

Block surface must be clean and accurate. Coat gasket, when required, with a THIN coat of cement. Place right side up, correct end forward, on block. Using guide pins, lower head into position. Head bolts and holes in block must be clean and coated with thread compound. Torque head.

Grind rocker arm ends that contact valve. Check fit on rocker shaft. Inspect ball or cup end. Push rods must be clean, straight, and smooth on the ends.

True up mechanical lifters on a valve grinder.

Disassemble, clean, inspect, and reassemble hydraulic lifters. When assembling, the parts must be CLEAN. Lubricate and install. Lubricate and install rocker arms on shaft. Make certain shaft has correct end forward and that rocker oil holes face towards the head (usual). Tighten shaft brackets slowly and evenly. This will allow the hydraulic lifters to leak down. Rocker arm valve clearance adjustment screws should be backed off. Use a torque wrench for final tightening. The ends of the lifters, push rods, and rocker arms should be lightly coated with lubricant.

When an adjustment is provided, center lifter plunger. With mechanical lifters, adjust valve stem-to-rocker arm clearance. In both cases, lifter must be on cam base circle. When engine is thoroughly warm, head should be retorqued and the valve clearance reset.

Accurate angles, clearances, and fits, coupled with absolute cleanliness, are absolutely essential to a top-notch valve service job.

CHECK LIST: If you have performed a thorough job, you will be able to answer each of the following questions with a definite YES.

VALVE:

1. Is the valve face clean, smooth, and correctly angled?
2. Is the margin 1/32 in. (0.79 mm) or larger?
3. Is the stem smooth and free of excessive wear and nicks?
4. Is the stem end ground square and slightly chamfered?
5. Are the keeper grooves clean and in good shape?
6. Is all carbon and gum removed?

SEAT:

1. Is the seat smooth, clean, and correctly angled?
2. Is the seat width as specified by manufacturer?
3. Does the seat contact the center of the valve face?
4. Is the seat concentric with the guide?
5. Is seat runout within .002 in. (0.05 mm)?
6. If an insert is used, is it tight in the head?
7. Is the seat width constant all the way around?

HEAD:

1. Was the head removed after cooling down?
2. Is the head immaculately clean, inside and out?
3. Is any distortion within limits?
4. Is the head-to-block surface free of scratches and dents?
5. Is the head free of cracks? If any were found, were they repaired?
6. Is the head gasket correctly installed?
7. If cement was used, was a THIN coat applied?
8. Is the head properly torqued?

GUIDES:

1. Is guide wear within limits?
2. If guide was replaced, was it correctly installed?
3. If guide was reamed, does it have the correct clearance?
4. If guide seals were used, are they properly installed?

ROCKER ARMS:

1. Is the end contacting the valve stem smooth and accurately ground?
2. Where oil holes are used, are they open?
3. Is the rocker shaft or ball stud bearing surface smooth and within wear limits?
4. Is the push rod ball or socket end smooth and free of wear?
5. Is the rocker correctly installed and does it contact the valve properly?
6. Is the rocker clean?

ROCKER SHAFT AND BALL STUDS:

1. Is the rocker shaft clean - inside and out?
2. Are the rocker arm bearing areas smooth and within limits?
3. Is the correct end of the shaft forward?
4. Do the rocker arm oil holes face in the correct direction?
5. Are the shaft brackets in the correct location, torqued, and free of cracks?
6. Is ample oil reaching the assembly?
7. If an overflow pipe is used, is it correctly located?
8. Are the ball studs tight in the head?
9. Are the ball stud adjusting nut threads in good shape?
10. Are the ball stud nuts within breakaway specs?
11. Are the self-locking rocker arm valve clearance adjusting screws within breakaway specs?

PUSH RODS:

1. Are the rods straight?
2. Are rod ends smooth and free of excessive wear?
3. If the rods carry oil, is the hollow section thoroughly clean?
4. Is the correct end up?
5. Are both ends in proper contact?
6. Are the rods, if no clearance adjustment is provided, the correct length?

LIFTERS:

1. Have the mechanical lifters been trued on the grinder?
2. Are ends and sides smooth and free of wear and galling?
3. Is the lifter-to-lifter bore clearance correct?
4. Are the hydraulic lifters immaculately clean and in good condition?
5. Have the hydraulic lifters been checked for leakdown?

VALVE LASH OR CLEARANCE:

1. If mechanical lifters are used, is the valve stem-to-rocker arm clearance as specified?
2. Was the clearance rechecked after thorough engine warmup and head retorquing?
3. Was the lifter on the base circle when the clearance was set?
4. Are all adjustment screws and locknuts tight?
5. If hydraulic lifters are used, were they set so that the plungers are near the center of their travel?

GENERAL:

1. When possible, were all parts replaced in the location from which they were removed?
2. Were all parts thoroughly cleaned?
3. Were all parts properly lubricated before assembly?

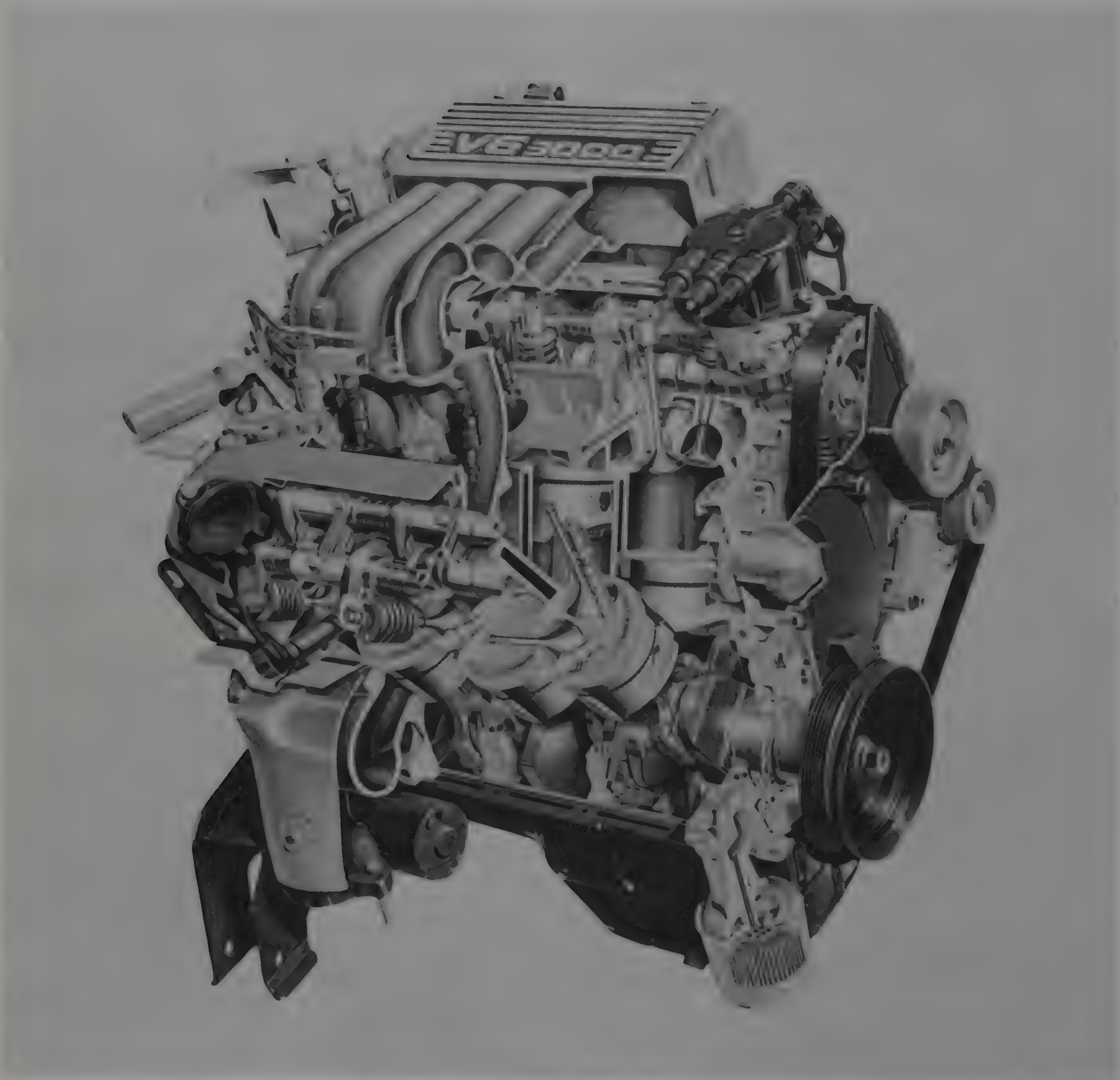
KNOW THESE TERMS

Cylinder head, Ball stud, Push rod, Split keepers, Sodium filled valve, Valve stem, Valve face, Valve face angle, Stem runout, Valve grinder, V-block, Small hole gauge, Reaming, Umbrella seal, Valve seat insert, Stellite, Peening, Insert recess cutter, Stone sleeve, Stone sleeve pilot, Adjustable pilot, Integral seat, Concentricity, Prussian blue, Straightedge, Valve stem height, Valve spring compressor, Torquing sequence, Roller lifter, Hydraulic lifter, Mechanical lifter, Leakdown rate, Rocker arm, Valve lash, Base circle, Cam flank, Feeler gauge, Valve seat runout, Overhead cam, Interference angle, Rocker arm cover, Valve stem clearance, Dial indicator, Integral guide, Counterbore, Oversize stem, Teflon seal, Swaged insert, Spring free length, Spring squareness, Valve float, Push rod runout, Push rod seat, Tappet clearance, Breakaway torque.

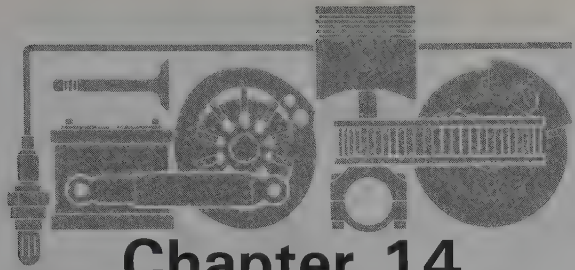
QUIZ - Chapter 13

1. Cylinder heads should be COLD before removing. [✓ True] or False?
2. Remove rocker arm assembly by:
   a. Loosening each bracket all the way before going to the next one.
   [✓ b.] Loosening each bracket, in turn, a little until all are loose.
   c. Loosening the front end first.
   d. Leaving one bracket tight until all others have been loosened.
3. Remove cylinder head bolts in the reverse order of the tightening sequence. [✓ True] or False?
4. It is necessary to keep all parts in order because:
   a. They may be lost.
   b. They can be kept in a smaller area.
   [✓ c.] It is important they be returned to their original positions.
   d. It is just a good habit.
5. Valve grinding stones are dressed with:
   a. A file.
   b. Another stone.
   [✓ c.] A diamond.
   d. A hardened steel rod.

6. It is most important to keep wheels dressed because:
   a. They cut faster.
   [✓ b. They will produce accurate angles.]
   c. They wear longer.
   d. They look better.
7. When the valve is ground at a slightly different angle (about one degree) than the seat, an interferience fit is produced.
8. When grinding the valve face:
   a. Keep the valve in the center of the stone.
   [✓ b. Move the valve back and forth - staying on the stone.]
   c. Move the valve back and forth - off both sides of the stone.
   d. Keep the valve on the right hand side of the stone.
9. To control stem height above the head, it is necessary to grind the Valve Stem end.
10. Explain how valve stem-to-guide clearance is checked. with a dial indicator
11. Where excessive valve stem-to-guide clearance is present, it may be corrected by Remed oversize guides or by re placed for an oversize valve stem.
12. Seals are often used on both the integral and the valve and removal. valve stem
13. Excessive exhaust valve-to-guide clearance will cause considerable oil consumption. [✓ True] or False?
14. A cracked valve seat can often be repaired by installing an insert.
15. Common valve seat angles are 45 and 30 degrees.
16. A valve seat that is too wide will:
   [✓ a. Pack with carbon, start to leak, and burn.]
   b. Run too cold.
   c. Break the valve stem.
   d. Be hard to open.
17. The valve seat should engage the valve face near the central. portion
18. To narrow a valve seat, metal should be removed from the top with a 15 or 30 degree stone.
19. Once the valve seat stone is dressed, approximately twelve seats may be ground before dressing again. True or [✓ False?]
20. The pilot for the seat stone sleeve should fit the guide hole.
21. The valve seat must be concentric with the guide hole. [✓ True] or False?
22. Seat runout should be kept within approximately:
   [✓ a. .002 in. (0.05 mm).]
   b. .006 in. (0.15 mm).
   c. .020 in. (0.51 mm).
   d. .0003 in. (0.0762 mm).
23. Valve springs should be tested for tension and Savarnes.
24. Excessive valve spring installed height can cause:
   a. Heavy spring tension.
   b. Valve float.
   [✓ c. Slow valve timing.]
   d. Seal damage.
25. Gasket cement must ALWAYS be applied to the head gasket. True or [✓ False?]
26. To facilitate accurate head, gasket, and block alignment, guide pin should be used when installing the head.
27. The rocker arm end that contacts the valve should be ground smooth and FLAT. True or [✓ False?]
28. Hydraulic lifter parts are all very accurately made and are thus all interchangeable. True or [✓ False?]
29. Following cleaning and reassembly, hydraulic lifters should be tested for leak down rate
30. All valves, lifters, push rods, rockers, and other parts should always be installed in the same spot from which removed. [✓ True] or False?
31. The rocker arm brackets, once the push rods are installed, should be drawn down to the head as rapidly as possible. True or [✓ False?]
32. Rocker shaft and rocker arm oil holes usually face:
   a. Away from the head.
   [✓ b. Toward the head.]
   c. Sideways.
33. Hydraulic lifter plungers should be about in the center of their travel when properly installed and adjusted. [✓ True] or False?
34. When adjusting valve clearance, the lifter should be on the nose of the cam. True or [✓ False?]
35. Excessive valve clearance will:
   a. Increase horsepower.
   b. Cause early valve opening.
   c. Prolong the life of the valve.
   [✓ d. Cause late valve opening and a lower lift.]
36. Valve clearance can be checked with a Feeler Gauge or a dial indicator.
37. Some heavy duty engines use Roller lifetor to reduce friction and extend camshaft lobe life.



Cutaway view of a 3.0-liter, V-6 engine. It produces 142 horsepower at 5000 rpm and 168 ft.-lbs. of torque at 2500 rpm. A six-throw crankshaft with evenly spaced firing sequences keeps vibration to a minimum. (Mitsubishi)



Chapter 14

CRANKSHAFT, MAIN BEARING, FLYWHEEL SERVICE

After studying this chapter, you will be able to:

☐ Remove and install a crankshaft.

☐ Check crankshaft and main bearing bores for problems.

☐ Install new main bearing inserts and rear seal.

☐ Measure main bearing clearance and crankshaft end play.

☐ Service a flywheel.

REMOVING CRANKSHAFT

The first step in removing a crankshaft is to remove the oil pan. Then, pull the vibration damper. Remove the front cover and then the chain, gear, or belt. Next, remove the piston and rod assemblies. When necessary, remove the oil pump, oil lines, and front engine plate. (See chapter on camshaft and chain, gear, or belt service.)

MARK CAPS BEFORE REMOVAL

Before removing the main bearing caps or cap, mark each cap and the crankcase web with a prick punch or number stamp. Place the cap and web marks on the same side. Never mark on the top of the cap. Use a heavy section near one side to prevent distortion, Fig. 14-1. One particular engine incorporates the use of a one-piece main bearing cap which has the five individual insert areas machined out. This is shown in Fig. 14-41.

MAIN BEARING CAP REMOVAL

Remove locking devices if used, and crack each cap bolt loose. Remove all cap screws while watching for variations in diameter and length. If main bearing cap cross bolts are used, remove them BEFORE the cap bolts. Do not misplace the cross bolt crankshaft-to-cap spacers. Keep them in proper order, Fig. 14-2.

Carefully pry the caps free. LIGHT tapping with a plastic or rawhide hammer will help. NEVER POUND ON THE CAPS OR USE A PRY BAR BETWEEN THE CRANK JOURNAL AND THE CAP BORE. The caps may look husky but they can be damaged easily - use care. Some caps are designed to accept a special puller.

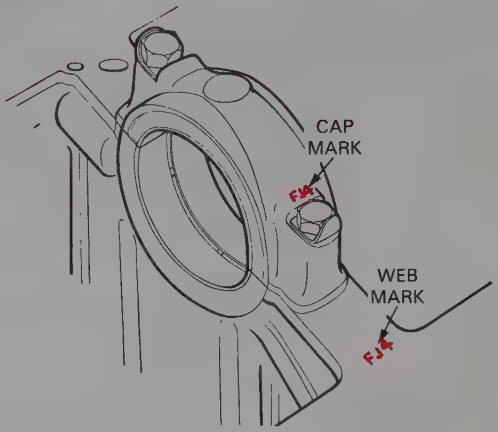


Fig. 14-1. Mark cap and web on same side before removing cap. (Jaguar)

LIFTING CRANKSHAFT FROM CRANKCASE

Lift the crankshaft STRAIGHT UP, being careful to avoid any damage to journal or thrust surfaces. If the crank is too heavy to handle by hand, use a sling and lift. Look at Fig. 14-3.

SPECIAL NOTE:

The maximum acceptable limit figures given in this chapter for bore alignment, bore out-of-roundness, shaft alignment, journal taper, and out-of-roundness are fairly small. Some manufacturers' specifications will call for even smaller limits. Some sources allow more.

The mechanic must use a great deal of discretion

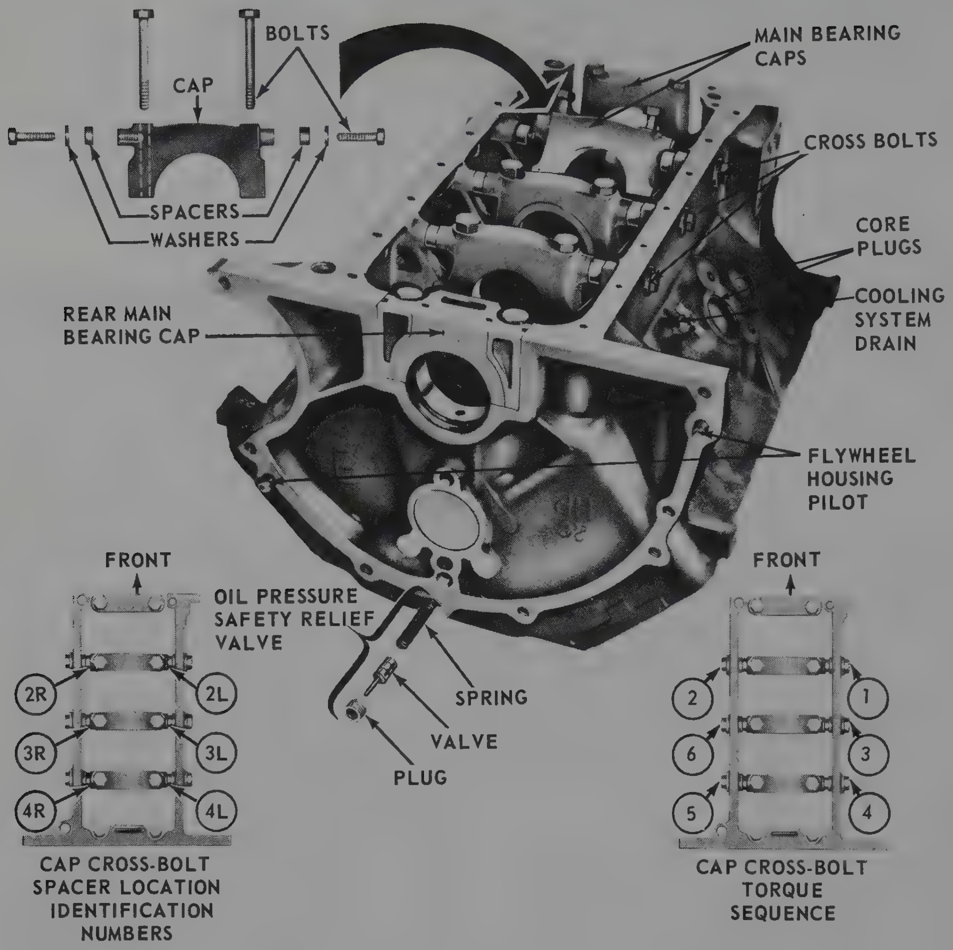

BOLTS
CAP
SPACERS
WASHERS
MAIN BEARING CAPS
CROSS BOLTS
CORE PLUGS
COOLING SYSTEM DRAIN
REAR MAIN BEARING CAP
FLYWHEEL HOUSING PILOT
FRONT
OIL PRESSURE SAFETY RELIEF VALVE
SPRING
VALVE
PLUG
2R
2L
3R
3L
4R
4L
CAP CROSS-BOLT SPACER LOCATION IDENTIFICATION NUMBERS
FRONT
2
1
6
3
5
4
CAP CROSS-BOLT TORQUE SEQUENCE

Fig. 14-2. Note use of main bearing crossbolts in this engine. (Ford)

deciding what the ACCEPTABLE limits are for the engine at hand. If the car is old and of little value, or if the owner only wants to "get by" for a short while, some mechanics feel these limits can be extended. Type of engine, use, and driving needs of the owner are also important factors.

Always give the owner an accurate appraisal of the condition and just what is needed for a PROPER repair. Carefully explain how service life is shortened, engine efficiency lowered, and how part failure can occur if limits are overextended.

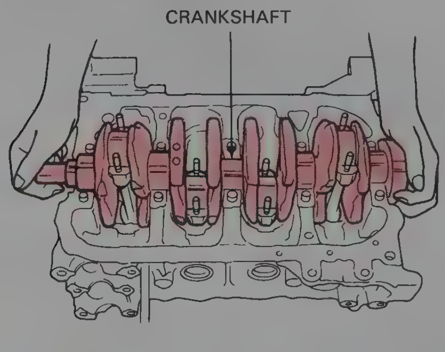

CRANKSHAFT

Fig. 14-3. Removing crankshaft by hand. Be careful! If too heavy, use a lift and sling. (Honda)

Many shops refuse to do any work that is not up to high standards. Others will perform the work but only after a written agreement with the customer in which the hazards are set forth. No guarantee is given.

CHECK MAIN BEARING BORES

Remove all the bearing inserts and mark them for study. Clean the web, cap bore, and parting surfaces. Install and TORQUE all caps. Using an inside micrometer, carefully check the bores for distortion (out-of-roundness). Distortion greater than around .0015 in. (0.0381 mm) will require correction in one of two ways. Undersize, semifinished inserts can be installed and align bored or material can be ground from the cap parting edges. The caps are then replaced, torqued, and align bored to their original specifications. The latter technique is preferred in that standard size precision inserts may be used. Any future work on the crankshaft bearings will also be facilitated.

If the individual main bearing bores are acceptable, they must then be checked for alignment.

A study of the bearing inserts will indicate bore misalignment. Wiping of bearing insert surfaces will usually be more evident at the center mains and diminishing toward both ends of the crank.

An aligning bar, about .001 in. (0.025 mm) smaller than bore specifications, may be placed in the main bores. The parting surfaces and bores must be CLEAN, and the caps torqued. The bar should turn by hand using a bar or wrench with a handle of 12 in. (304.8 mm) or less in length. If you cannot turn the bar, the bores are out of alignment. Make sure no caps were reversed. Alignment can also be checked by placing an accurate straightedge across the bores. Keep the straightedge parallel to the bore centerline. Check in several different positions. If a .0015 in. (0.0381 mm) feeler can be inserted between straightedge and any bore, alignment must be corrected. Removal of material from the cap parting sufaces, followed by align boring, is the preferred method of correction.

REMEMBER: Proper clearance between insert and journal requires ROUND bores in PROPER ALIGNMENT.

CLEANING CRANKSHAFT

The crankshaft must be thoroughly cleaned. Use a rifle type brush to scour out oil channels. Follow by heavy flushing. Then blow dry with air. Lightly oil all journal surfaces immediately.

CHECK MAIN AND ROD JOURNALS FOR FINISH AND ACCURACY

Place the crankshaft on a pair of SMOOTH, CLEAN, and OILED V-blocks. If the blocks are not absolutely smooth, cover the V's with thin, hard paper. Turn the shaft slowly and visually check each journal for signs of scratching, ridging, scoring, or nicks. You will often note a dark line around the journal. This is caused by the oil groove in the insert and is not harmful unless it protrudes more than .0003-.0004 in. (0.0076-0.0102 mm) above the surface of the journal. This dark line should be polished with CROCUS cloth (extremely fine abrasive) to remove any accumulated carbon or gum.

Crocus cloth may also be used to remove any small burrs caused by tiny nicks or scratches. Pull the cloth around the journal and apply a "shoe shine" motion. By keeping the cloth pulled around one-half of the journal, the polishing will not produce flat spots.

All journals must be absolutely SMOOTH. Any roughness, ridging, or scoring will require grinding to remove. The shaft in Fig. 14-4 is badly scored.

If the journal surfaces are in good shape, they must then be checked for out-of-roundness, taper, and wear.

The journal must be measured, near one end, in several spots around the diameter. Be careful to keep off the corner fillet radius. Write down each measurement. Repeat this process near the other end of the journal, Fig. 14-5.

OUT-OF-ROUNDNESS, TAPER, AND UNDERSIZE

The measurements in Fig. 14-5 will determine three important points: out-of-roundness, taper, and undersize.

Out-of-roundness will be computed by figuring the difference in diameter measurements at various points. OUT-OF-ROUNDNESS MUST NOT EXCEED

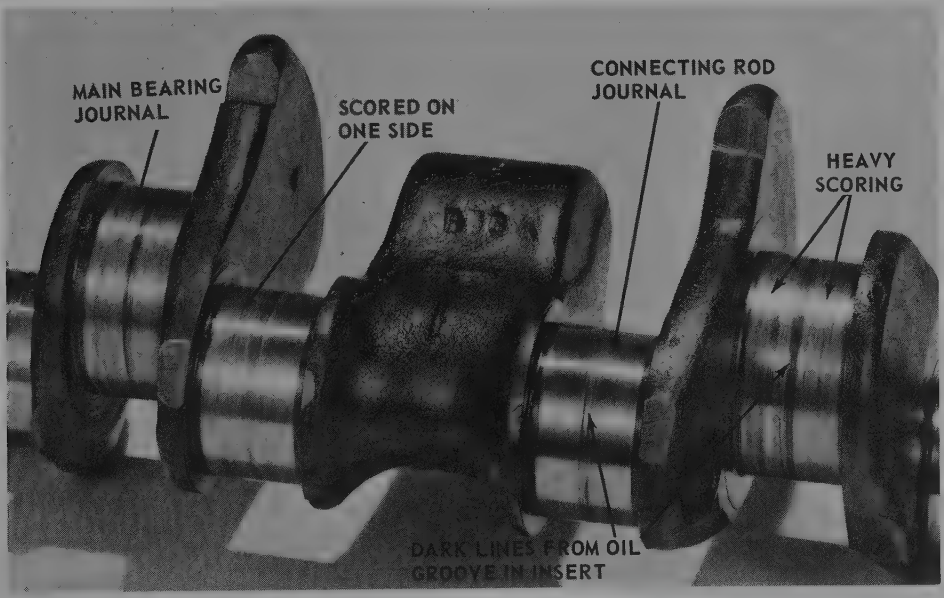


Fig. 14-4. Journals on this crankshaft are badly scored. Shaft must be reground. (Clevite)

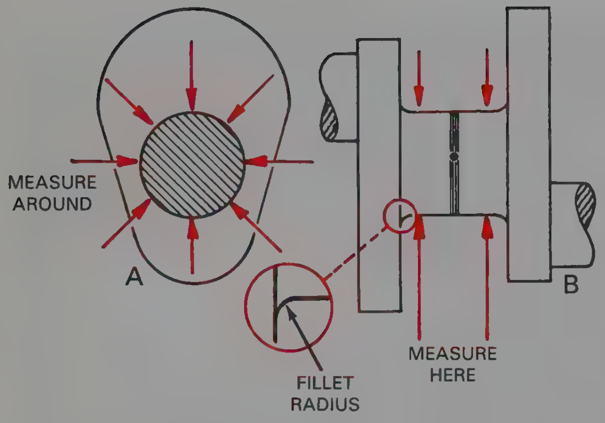


Fig. 14-5. A—End cross-sectional view of journal. B—Side view. Make measurements as indicated.

.001 in. or 0.025 mm. Fig. 14-6 illustrates three journals - one within limits (would accept a standard size insert), one requiring grinding, and one within limits but worn .001 in. (0.025 mm) undersize (would accept a .001 in. [0.025 mm] undersize insert).

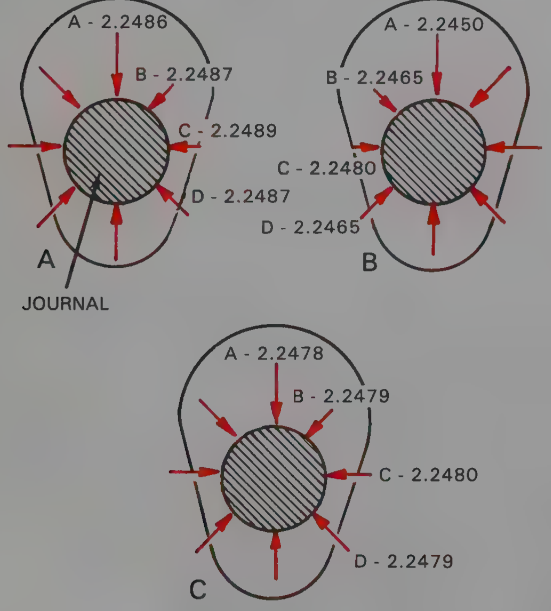
You will note that the journal in A, Fig. 14-6, is only .0003 in. (0.0076 mm) out-of-round and has worn a mere .0001 in. (0.025 mm). Providing the taper is within limits, this journal will be satisfactory. If a new insert is required (it pays to use new ones) a STANDARD SIZE is required.

In B, Fig. 14-6, the journal is .003 in. (0.08 mm) out-of-round, and has worn a maximum of .001 in. (0.025 mm). This journal is unfit for service and should be reground.

In C, Fig. 14-6, the journal is only .0002 in. (0.0058 mm) out-of-round, but has worn an even .001 in. (0.025 mm). If the taper is satisfactory, this journal can still be used but will require a .001 in. (0.025 mm) UNDERSIZE insert.

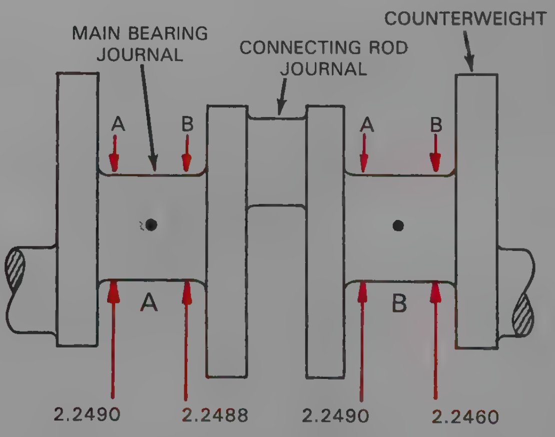
SELECTING CORRECT UNDERSIZE INSERT

With minor journal wear, in which the journal out-of-roundness and taper is within limits, the proper oil clearance can often be maintained by the installation of .001 or .002 in. (0.025 or 0.05 mm) undersize inserts. When determining the correct undersize, ALWAYS USE THE LARGEST JOURNAL MEASUREMENT. If the smallest measurement, or an average of all measurements, is used, there could be INSUFFICIENT OIL CLEARANCE and the bearings will quickly fail. If the largest measurement indicates the journal has worn .0005 in. (0.0127 mm) below standard, no undersize is required. For wear from .001 to .0019 in. (0.025 to 0.0482 mm), a .001 in. (0.025 mm) undersize is needed. For wear from .002 to .003 in. (0.050 to 0.080 mm), a .002 in. (0.050 mm) undersize will suffice. For wear much above .003 in. (0.080 mm) a .002 in. (0.050 mm) undersize will not bring the oil clearance within limits. An average oil clearance would be about .001 in. (0.025 mm) for each inch (25.4 mm)



	A	B	C
STANDARD DIAMETER =	2.2490	2.2490	2.2490
LARGEST DIAMETER - C =	2.2489	2.2480	2.2480
MINIMUM AMOUNT OF WEAR =	.0001	.0010	.0010
LARGEST DIAMETER - C =	2.2489	2.2480	2.2480
SMALLEST DIAMETER - A =	2.2486	2.2450	2.2478
MAXIMUM OUT-OF-ROUND =	.0003	.0030	.0002

Fig. 14-6. End cross-sectional view of three journals. A—OK for a STANDARD insert. B—Must be reground. C—OK but requires a .001 in. or 0.025 mm UNDERSIZE insert.



	A	B
LARGEST DIAMETER - A =	2.2490	2.2490
SMALLEST DIAMETER - B =	2.2488	2.2460
TAPER =	.0002	.0030

Fig. 14-7. Journal A has only .0002 in. (0.0051 mm) taper and is OK. Journal B shows a taper of .003 in. (0.08 mm) and must be reground.

of shaft diameter for pressure lubricated systems. Bearing material, engine design, and rpm all affect the amount of clearance required, so ALWAYS check the manufacturer's specs.

TAPER

By computing the difference in diameter readings between both ends of the journal, the amount of taper can be determined. In A, Fig. 14-7, the journal taper is .0002 in. (0.0051 mm) and is thus acceptable. The journal in B shows a taper of .003 in. (0.08 mm) and must therefore be reground. TAPER SHOULD NOT EXCEED .001 in. (0.025 mm), Fig. 14-7.

Connecting rod journals tend to wear more out-of-round and tapered than do the main bearing journals. This is basically due to the fluctuating load that places certain areas of the journal under heavy, sudden stresses. Rod twist and bend exert uneven edge loading that tends to taper the journal.

CRANKSHAFT ALIGNMENT

Even though the journals are smooth and within limits, if the crankshaft is sprung out of alignment, bearing life will be greatly shortened.

Check the shaft by placing both end journals on a set of V-blocks. Adjust a dial indicator to the center or intermediate mains. Turn the shaft and record the amount of runout. Check each main journal. To record the end journals, move a V-block in to the intermediate main.

On long shafts, it may be necessary to support the shaft on the intermediate journals to prevent sag, as shown in Fig. 14-8, A. AVERAGE maximum (consult manufacturer's specs) misalignment should be held to .001 in. (0.025 mm) between journals and .002 in. (0.050 mm) overall. Remember that any journal out-of-roundness must be taken into consideration, as it will affect the indicator reading.

If the crankshaft is only slightly out of alignment, it may be possible to straighten it. This can be done by either cold bending, bending with pressure and heat, and in some cases, through the application of heat alone. In general, forged steel crankshafts will allow a greater degree of straightening than the semisteel cast types. Fig 14-8, B, illustrates one type of straightening tool.

REGRINDING CRANKSHAFT

Crankshaft regrinding is a specialty operation. Most auto shops do not have the necessary heavy equipment. They send or "farm" out such jobs as crankshaft and camshaft grinding, reboring, align boring, shaft straightening to machine shops.

Crankshaft grinding requires accurate machinery and a skilled operator. Tolerances must be held to close limits and finishes must be extremely smooth (16 micro inch or smoother).

The shaft is cleaned, checked for alignment, and if necessary, straightened. It is then set up in the grinder and the journals ground to suitable undersize.

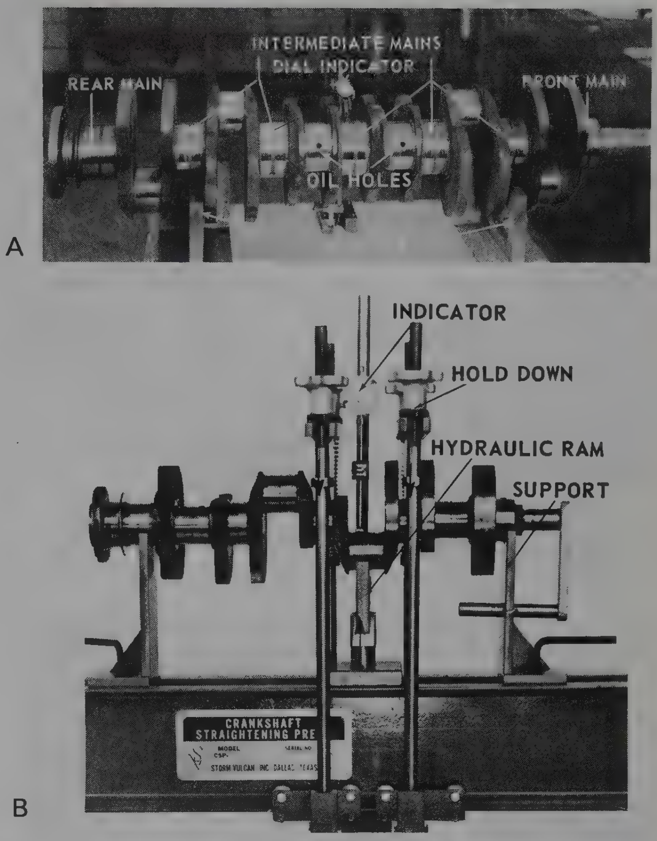


Fig. 14-8. A—Using a dial indicator and V-blocks to check crankshaft alignment or straightness. (Clevite) B—Straightening a crankshaft in a special press.

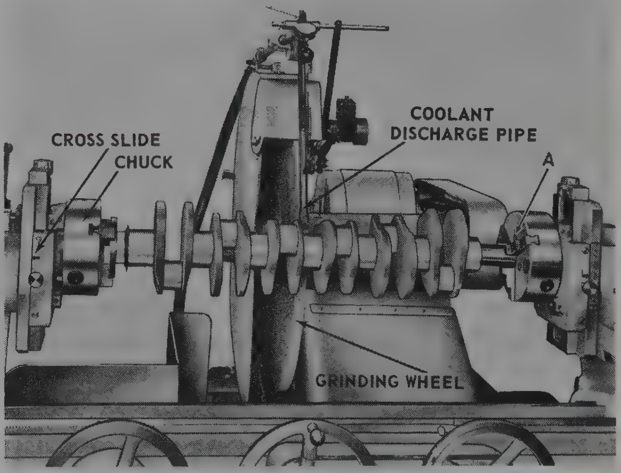


Fig. 14-9. Regrinding a crankshaft. (Van Norman)

The journal showing the most wear is miked. The amount of material to be removed to "clean it up" is determined. Material may be removed in multiples of .010 in. (0.25 mm). All other related journals are then ground to the same undersize. Fig. 14-9 shows a crankshaft set up for grinding. Note the graduated cross slides for offsetting shafts the proper amount.

The amount of material that may be safely removed depends on a number of considerations. Shaft material, size, engine HP, RPM, and operating conditions all enter the picture. Grinding to .010, .020, .030 in. (0.25, 0.51, 0.75 mm) undersize is commonly done. Some shafts will stand .040 in. (1.01 mm) or more.

The machine operator will maintain the same fillet radius at each corner of the journal.

CRANKSHAFT WELDING, SPRAYING, AND PLATING

If one journal is damaged so badly that excessive undersize would result, the journal may be built up by spraying with molten steel, or by welding continuous arc weld beads around the journal, Fig. 14-10. Regardless of which method is employed, the journal is built up above its original diameter and then ground to the desired size.

Journals can also be built up a certain amount by electroplating with hard chromium.

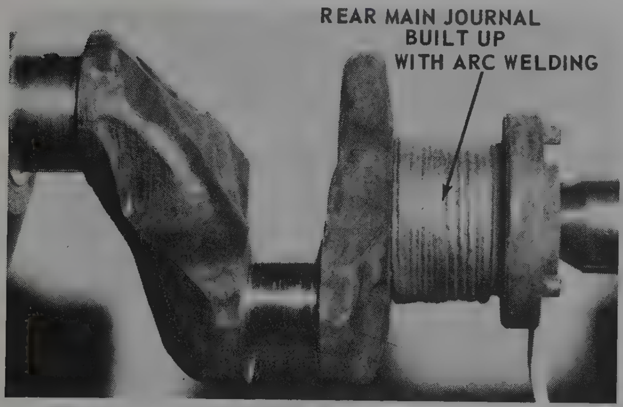


Fig. 14-10. A damaged journal built up by arc welding. Journal will be ground to proper size. (Storm-Vulcan)

POLISHING THE JOURNALS

A properly ground shaft may LOOK smooth but in reality the surface has thousands of tiny sharp edges. Following grinding, the journals should be polished to remove the abrasive-like fuzz. Each fillet radius and the shaft thrust surfaces should also be polished. A good polishing operation will produce an extremely smooth surface - 7 micro inch or smoother (16 micro inch finish is satisfactory). The operator in Fig. 14-11 is polishing a crankshaft following grinding.

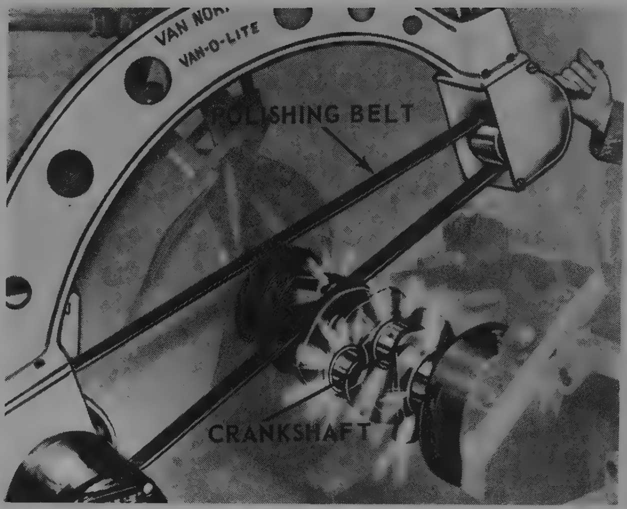


Fig. 14-11. Polishing crankshaft journals.

CHECK SHAFT FOR CRACKING

It is good practice to visually inspect the crankshaft for signs of cracking. Many shops check for cracking by using a special penetrating dye, or a magnetic process. (See chapter on soldering, welding, and crack detection.)

CLEANING AND STORAGE

Following grinding and polishing, the crankshaft should be thoroughly cleaned, oiled, and covered until ready to use. If the shaft is to be stored for some time, stand it ON END or support it in SEVERAL SPOTS. If the shaft is allowed to sag during storage, it can take on a permanent set (bend), throwing it out of alignment.

MAIN BEARING INSERT INSTALLATION

Inserts must be of the correct size, design, and material. The block, oil galleries, and bearing bores must be spotlessly clean. Fig. 14-12 illustrates a set of typical main bearing inserts for use in a V-8 engine. Note that only the upper halves are drilled for oil entry.

Some crankshafts have all mains of the same size. Others have the front main the smallest, with a gradual increase in size from front to back. If the engine uses the latter type, the inserts are not interchangeable. Look at Fig. 14-13.

Working on one bearing at a time, install the proper inserts. Bearing bores and insert back must be CLEAN and dry. The insert should snap into place. The locating lugs should fit the recess properly and the correct

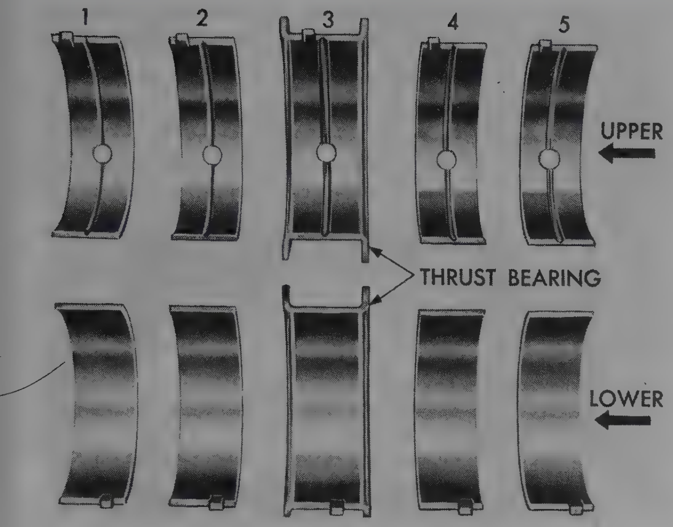

1
2
3
4
5
UPPER
THRUST BEARING
LOWER

Fig. 14-12. A set of main bearing inserts. Note that only upper halves are drilled for oil entry. (Dodge)

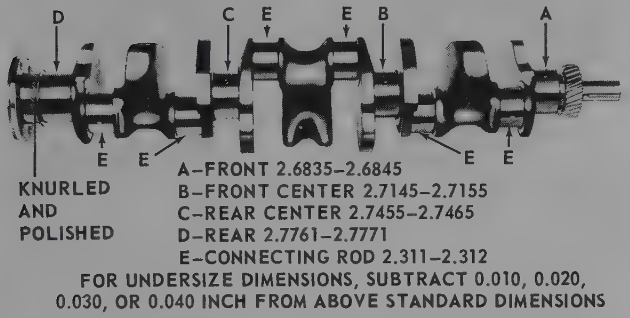

D
C
E
E
B
A
E
E
E
E
KNURLED AND POLISHED
A–FRONT 2.6835–2.6845
B–FRONT CENTER 2.7145–2.7155
C–REAR CENTER 2.7455–2.7465
D–REAR 2.7761–2.7771
E–CONNECTING ROD 2.311–2.312
FOR UNDERSIZE DIMENSIONS, SUBTRACT 0.010, 0.020, 0.030, OR 0.040 INCH FROM ABOVE STANDARD DIMENSIONS

Fig. 14-13. Six cylinder crankshaft with different size main journals. Notice knurled and polished area that contacts rear main seal. Angle of cuts tends to pull oil from under seal and back into engine. (G.M.C.)

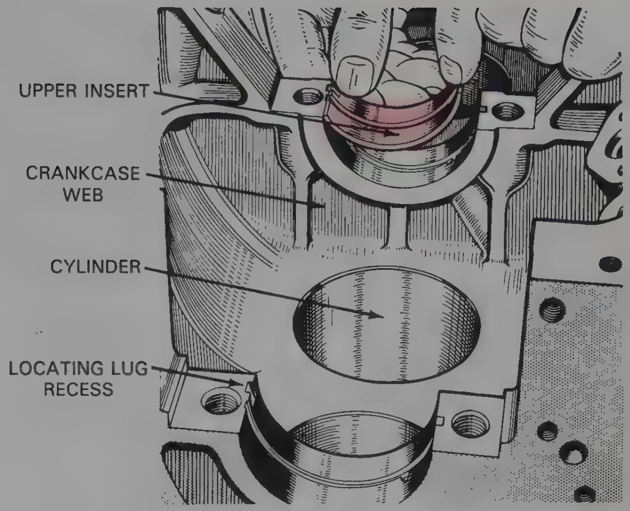

UPPER INSERT
CRANKCASE WEB
CYLINDER
LOCATING LUG RECESS

Fig. 14-14. Installing an upper main bearing insert.

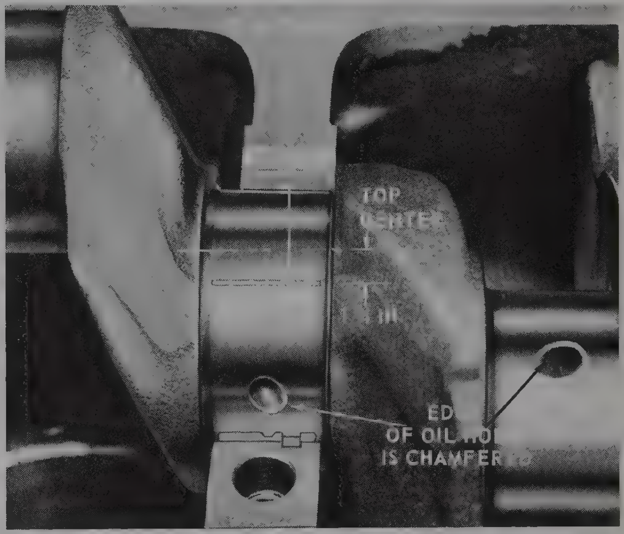

TOP CENTER
ED OF OIL HO IS CHAMFER

Fig. 14-15. Placing Plastigage on journal. It is placed slightly to one side of top center.

amount of crush should be evident. The bearing half that is drilled for oil entry must be placed in the upper or crankcase bore. Check each insert to be sure the oil hole aligns with the oil passageway. Some front main inserts are designed to facilitate timing chain lubrication. In such cases, make certain they are properly located. See Fig. 14-14.

CHECK BEARING CLEARANCE

Wipe a thin film of clean engine oil over the surface of all upper inserts. The rear main oil seal is LEFT out at this time. It tends to hold the shaft away from the bearing surface when checking clearance.

Carefully lower the crankshaft into position. Be careful to avoid damage to the thrust bearing flange surfaces. Rotate the shaft several times to seat the journals.

Using a CLEAN cloth, wipe off the top (exposed) surface of each journal. Place a length of Plastigage across each journal, about 1/4 in. (6.35 mm) from top center. The Plastigage should be as wide as the insert. Do not place it across an oil hole, Fig. 14-15.

Install the caps and torque. DO NOT ROTATE THE SHAFT UNTIL FINISHED WITH THE CLEARANCE CHECK AS THE PLASTIGAGE WILL BE SMEARED.

Remove each cap. Check the width of the Plastigage with the paper scale. Slide the scale over the flattened Plastigage until you find a marked band that is closest to the same width. The number on the band will indicate the clearance in thousandths. All bearings should show specified clearance, Fig. 14-16.

If there is a variation in the width of the flattened plastic (from one side of journal to other), this would indicate TAPER is present. The difference between the widest and narrowest section would determine the

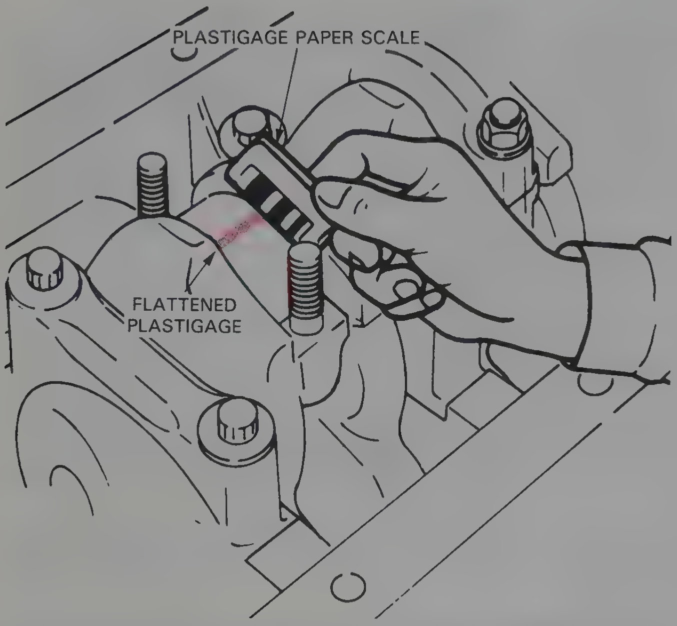


Fig. 14-16. Checking flattened Plastigage to determine clearance. (Chevrolet)

AMOUNT of taper.

Wipe off the Plastigage and remove the shaft.

OIL SEAL WARNING

A number of different designs are used to seal the rear main bearing against the passage of oil. Regardless of type, this is one operation that must be done with care. Far too often, this job is done in a haphazard manner.

Basically, oil can find its way into the flywheel housing by passing along the shaft, through the rear main parting surfaces, along the rear main cap edges (in some applications), and in one type, through the crankshaft flywheel flange bolt holes.

When installing the seal, give some thought to the basic setup and just how it prevents oil leakage.

REAR MAIN BEARING OIL SEALS

Two materials are commonly used for rear main bearing oil seals. They are ASBESTOS (graphite impregnated wick, woven rope) and NEOPRENE (synthetic rubber).

ASBESTOS WICK SEAL

The asbestos type, if PROPERLY installed, will perform well. It is good practice to soak the seal in engine oil for 30 minutes prior to installation.

Clean out the seal groove in the cap and crankcase bore. Lay one section of wicking over the groove in the upper bore. Starting in the CENTER, press the seal fully into the groove. Work up each side by pressing IN and DOWN to bottom the seal. When fully seated (about an equal amount should protrude above each parting surface), place an installing tool against the seal and tap into place. Refer to Fig. 14-17.

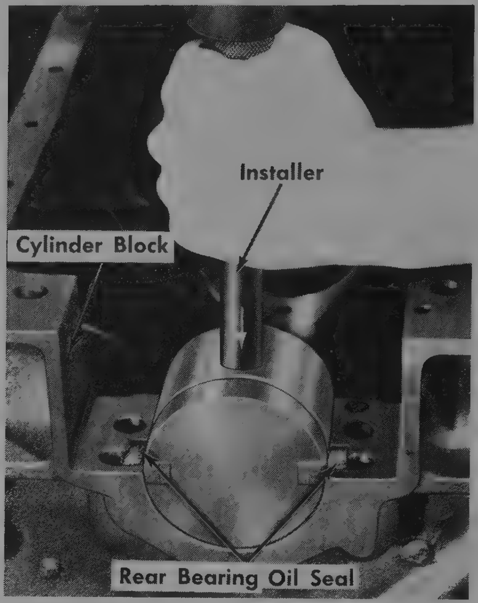


Fig. 14-17. Using a special installing tool to seat rear main upper oil seal.

When fully seated, keep the installing tool in place. Using a SHARP knife or razor blade, cut off the protruding seal ends FLUSH with the parting surface. MAKE CERTAIN NO LOOSE ENDS OF SEAL MATERIAL ARE LEFT THAT COULD JAM BE-

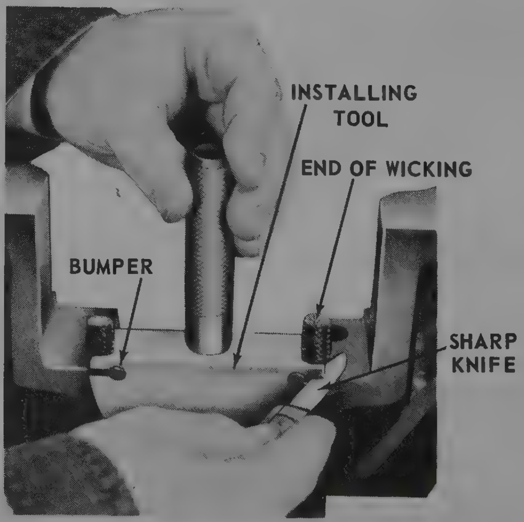


Fig. 14-18. Trimming seal ends flush with parting surface. Soft bumper protects knife edge as it passes through seal. (Ford)

TWEEN THE PARTING EDGES AND PREVENT THE CAP FROM SEATING. See Fig. 14-18.

Install seal wicking in the cap. If an installing tool is not available, a smooth, round bar or large socket may be used. Seat in the center and work the seal down and in toward the bottom. When fully seated, hold the bar against the seal opposite the parting edge and trim flush, Fig. 14-19.

The rear main cap used in a setup, such as shown in Fig. 14-20, utilizes side seals and cap screw plugs to prevent leakage. These must be carefully installed also.

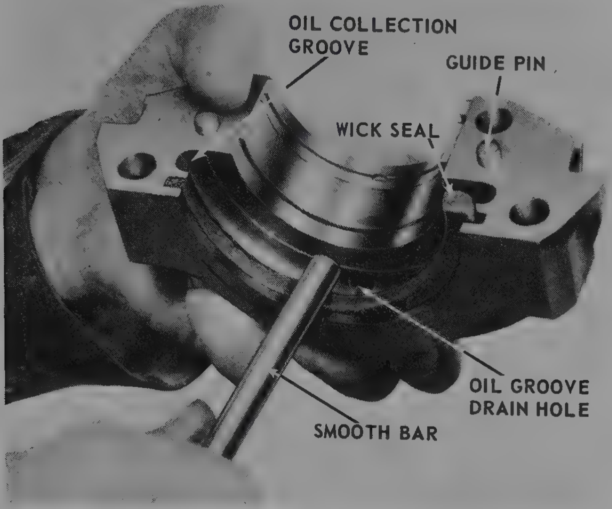
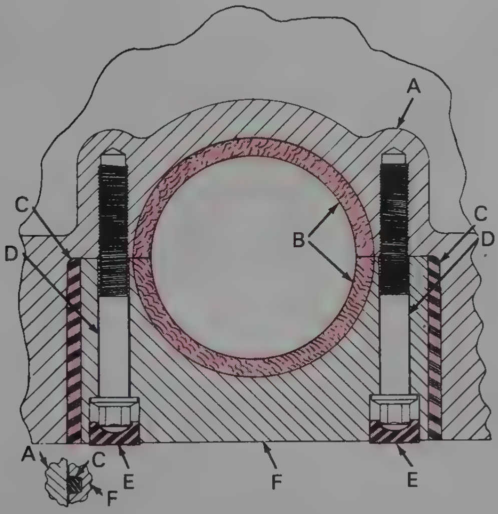


Fig. 14-19. Seating cap seal by using a smooth bar. Collection groove catches oil thrown off by slinger. Oil flows back into pan through collection groove drain hole. ALWAYS MAKE CERTAIN IT IS OPEN. (G.M.C.)



A —Cylinder block
B —Crankshaft oil seal
C —Bearing cap side seal
D —Bearing cap rear bolt
E —Plug
F —Rear bearing cap

Fig. 14-20. Rear main oil seals.

With parting edges clean, a THIN layer of sealer should be applied. Some coat only the last portion past the oil slinger. Some synthetic seals have a special glue on the ends. In these cases, be careful to avoid getting oil or sealer on the ends. Do not get sealer on the journal. Be sure the coating on the parting surface is not so heavy it will squeeze out onto the journal, Fig. 14-20.

SYNTHETIC SEALS

Instead of the wick type just discussed, a number of engines employ synthetic (neoprene) type main bearing seals, Fig. 14-21. Fig. 14-22 illustrates the procedure for removing a rear main bearing synthetic seal. This seal is a split (two piece) type.

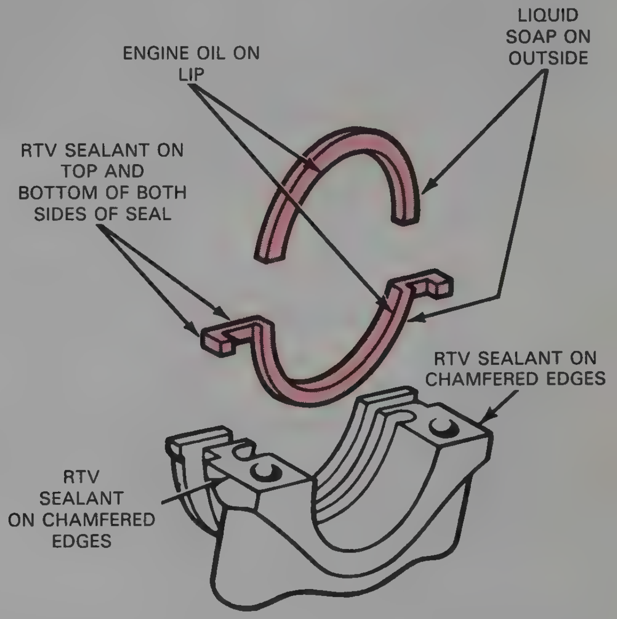

LIQUID SOAP ON OUTSIDE
ENGINE OIL ON LIP
RTV SEALANT ON TOP AND BOTTOM OF BOTH SIDES OF SEAL
RTV SEALANT ON CHAMFERED EDGES
RTV SEALANT ON CHAMFERED EDGES

Fig. 14-21. A "split" (two piece) synthetic crankshaft rear main bearing seal. Use oil on seal lips. Apply sealer as directed by manufacturer. (American Motors)

Install split seal carefully according to manufacturer's directions. Use engine oil on seal lips and apply sealer where needed. Fig. 14-21 shows the recommended coatings for one specific engine.

Other engines utilize a one piece (continuous) rear main bearing seal. Remove carefully. Clean recess. Coat as required. Using a seal guide to prevent seal damage, drive seal into place. Make certain seal lip faces inward and that shaft seal contact area is smooth. Use a special seal driver. Study Figs. 14-23, 14-24, and 14-25.

INSTALLING CRANKSHAFT

Wipe a heavy film of oil on all bearing surfaces. Lower the crankshaft into place. Place caps in posi-

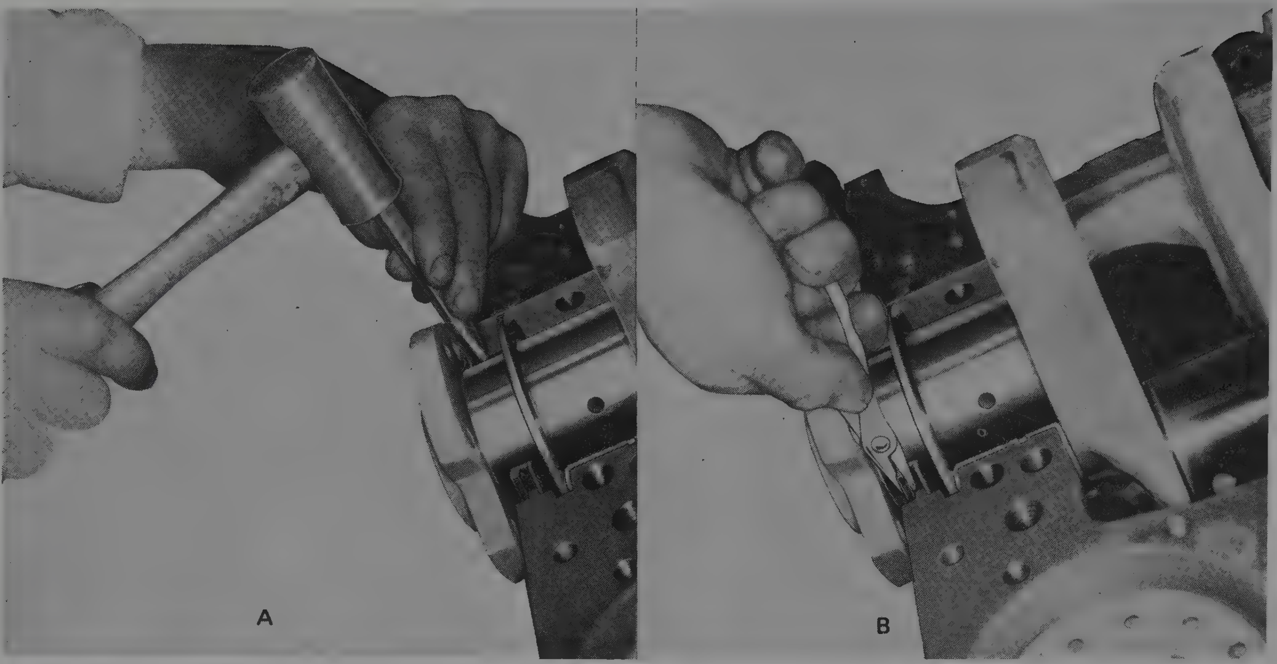


Fig. 14-22. Removing a synthetic rear main bearing upper seal. A—One end of seal is tapped down with a punch until opposite end protrudes far enough to grasp with pliers. B—Seal is then pulled from groove. (Chevrolet)

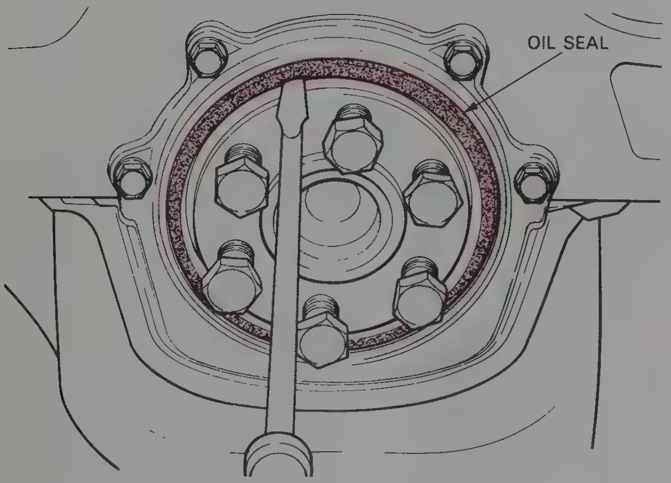


Fig. 14-23. Removing a continuous (one piece) synthetic rear main bearing oil seal. Do not scratch or nick seal lip contact surface. (Chrysler)

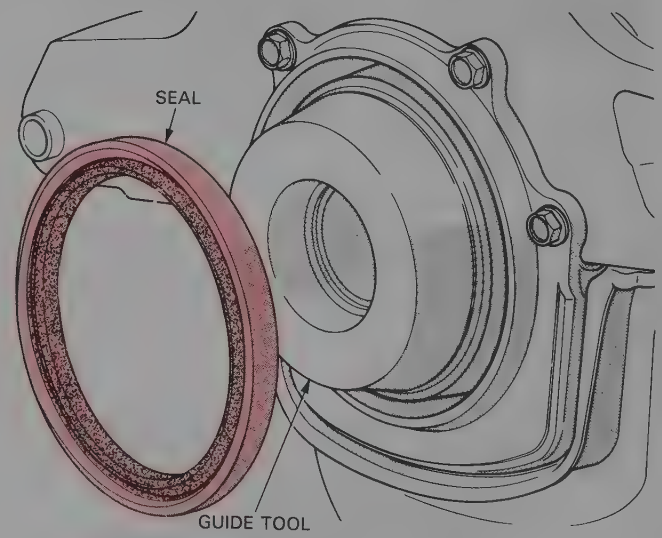


Fig. 14-24. When installing one piece rear main bearing seal, use a properly designed seal installation guide tool to prevent seal damage. Use oil on seal lip and crank seal contact surface. Coat seal outer diameter with recommended sealer. Guide must be clean and lightly oiled. (Chrysler)

tion. Do not reverse them - check your marks. Run up snugly. Leave the thrust bearing cap loose. Tap caps lightly with a plastic mallet to assist in alignment. Torque all the caps except the one used for the thrust bearing.

Pry the shaft forward against the lower thrust flange. While holding the shaft forward, pry the cap back to force the cap thrust flange against the shaft thrust surface. Maintain forward pressure on shaft and torque cap. This will assure an even contact between crank and thrust bearing flanges, Fig. 14-26.

CHECKING CRANKSHAFT END PLAY

A dial indicator or a feeler gauge may be used to check crankshaft end play. If a feeler gauge is used, force the shaft to the limit of its travel in one direction. Slip a feeler gauge between the insert thrust flange and the crank thrust face on the free side. This will let you determine clearance. AVERAGE CRANK-

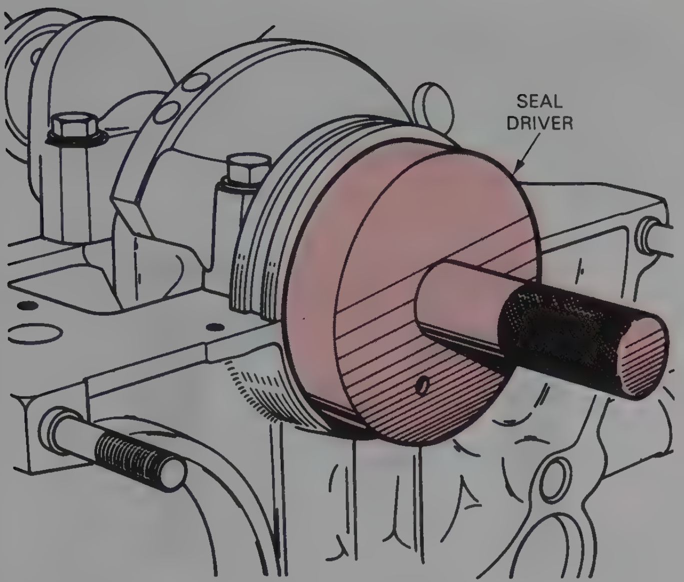

SEAL
DRIVER

Fig. 14-25. One type of seal driver used for installing one piece rear main bearing oil seals. (Renault)

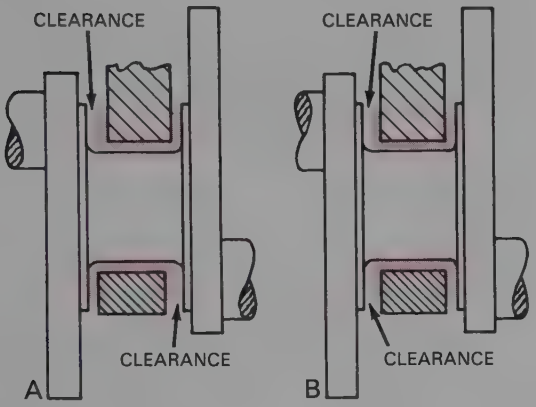

CLEARANCE
CLEARANCE
CLEARANCE
CLEARANCE
A
B

Fig. 14-26. Upper and lower insert thrust flanges must be aligned with crankshaft thrust surface. A—Shaft would have NO END PLAY due to misaligned flanges. B—Shaft would have correct end play as flange alignment is OK.

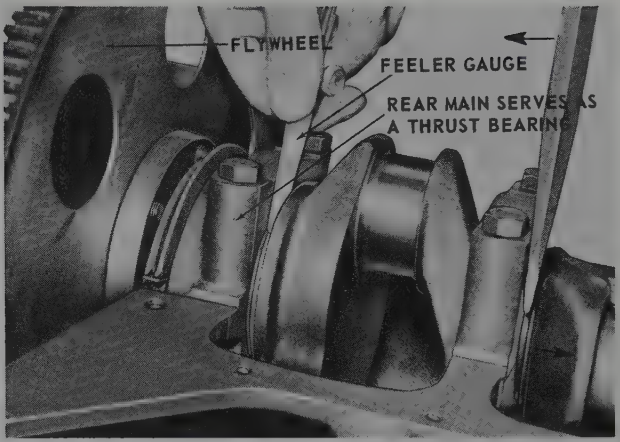

FLYWHEEL
FEELER GAUGE
REAR MAIN SERVES AS
A THRUST BEARING

Fig. 14-27. Checking crankshaft end play with a feeler gauge. (Chevrolet)

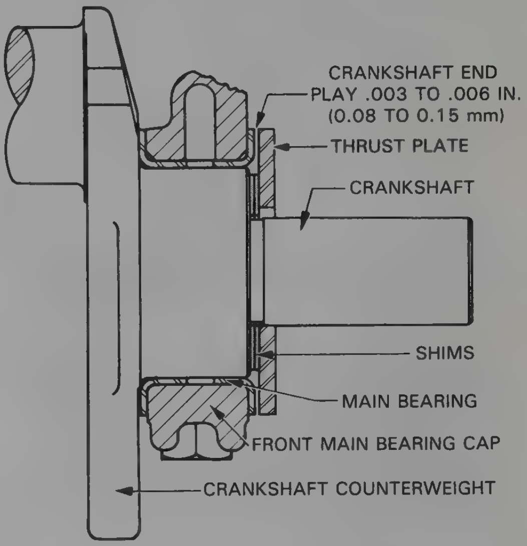

CRANKSHAFT END
PLAY .003 TO .006 IN.
(0.08 TO 0.15 mm)
THRUST PLATE
CRANKSHAFT
SHIMS
MAIN BEARING
FRONT MAIN BEARING CAP
CRANKSHAFT COUNTERWEIGHT

Fig. 14-28. End play in this shaft is adjustable through use of shims.

SHAFT END PLAY RANGES FROM .004 to .008 in. (0.10 to 0.20 mm).

Do not jam the feeler blade into the clearance area because the thrust bearing flange could be marred. See Fig. 14-27.

Some engines utilize a thrust plate that allows end play to be adjusted by adding or removing shims. This setup is used on the front of the shaft, Fig. 14-28.

MEASURING CRANKSHAFT MAIN JOURNALS—ENGINE IN CAR

At times, it may be desirable to install new main bearings without removing the engine from the car. To select the proper replacements, it is necessary to measure each journal.

There are several different types and styles of measuring devices. One is a gauge that will allow the shaft to be measured without rolling out the upper insert. To use this gauge, the journal and gauge contact pads are wiped clean. The central plunger is locked down and the gauge placed against the shaft. The plunger is released and when in full contact with the shaft, locked with the thumbscrew. A regular outside micrometer is used to measure across the length of the plunger. This distance is the radius (one-half diameter) of the shaft. It must be doubled to determine shaft diameter. As with all precision measuring tools, this gauge requires practice and extreme care in use, Fig. 14-29.

Another type is, basically, an outside micrometer with special caliper type jaws. It requires that the upper insert be rolled out to allow room for jaw entrance. Look at Fig. 14-30.

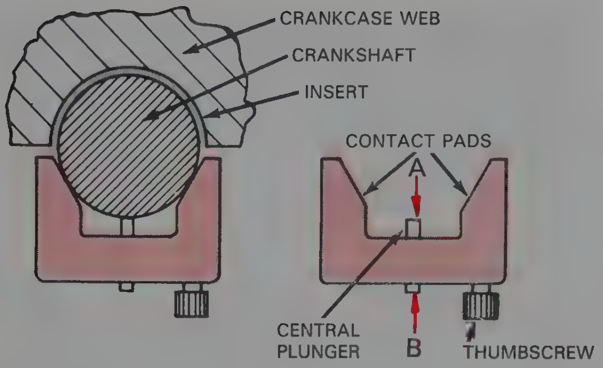

CRANKCASE WEB
CRANKSHAFT
INSERT
CONTACT PADS
A
CENTRAL PLUNGER
B
THUMBSCREW

Fig. 14-29. Crankshaft main journal gauge. Measure distance A-B and DOUBLE. Note how gauge is placed against journal and that insert may be left in place.

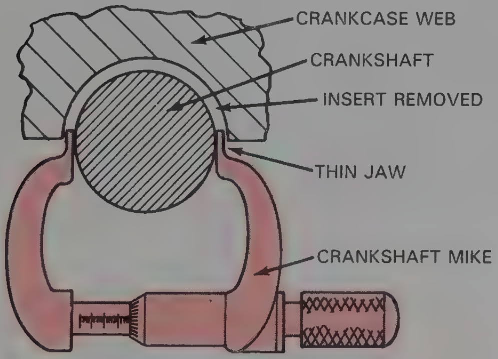

CRANKCASE WEB
CRANKSHAFT
INSERT REMOVED
THIN JAW
CRANKSHAFT MIKE

Fig. 14-30. Special crankshaft micrometer. Thin jaws will enter between journal and bore after insert is removed.

Whatever type of measuring tool is used, use care as it is EASY to make a poor reading. Rotate the shaft so you will have a measurement at several points.

REMOVING THE CRANKSHAFT MAIN BEARING UPPER INSERTS—ENGINE IN CAR

On many engines, it is possible to remove and replace the upper main bearing inserts with the engine in the car. Loosen the front and rear caps but do not remove. This will assist in the removal of the intermediate bearing inserts. Remove the intermediate caps. Insert a suitable removal plug. The plug must enter the journal oil hole. The flat section must be a little narrower and thinner than the insert to prevent binding in the bore. It should contact the inset end squarely, Fig. 14-31.

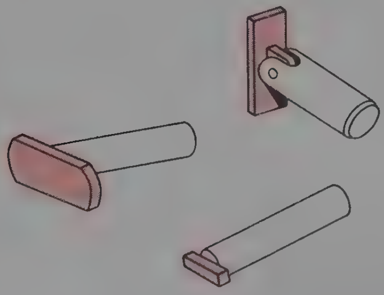


Fig. 14-31. Typical insert removal plugs. (Clevite)

In an emergency, a plug can be made from a cotter pin, Fig. 14-32.

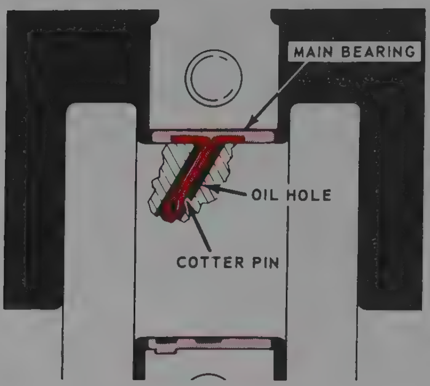

MAIN BEARING
OIL HOLE
COTTER PIN

Fig. 14-32. A cotter pin can be used as a removal plug.

Rotate the shaft to bring the flat section of the plug against the insert end OPPOSITE the locating lug. Make sure it will clear the bore. Slowly rotate the shaft and the insert will be forced around and out, Fig. 14-33.

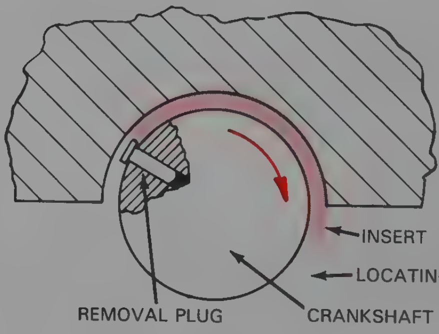

INSERT
LOCATING LUG
REMOVAL PLUG
CRANKSHAFT

Fig. 14-33. As shaft is rotated, removal plug will force insert out.

ROLLING IN THE NEW INSERT

The upper bore and crank journal should be thoroughly cleaned. DO NOT LEAVE ANY LOOSE THREADS OF CLOTH IN THE BORE. Lubricate the journal and insert. Place the insert against the journal, plain end toward the bore locating lug recess. Slip insert into bore as far as possible. Place the removal plug in the oil hole and rotate against the locating lug end of the insert. Continue rotation until insert is properly seated. MAKE CERTAIN THE INSERT LOCATING LUG ENGAGES THE LUG RECESS IN THE BORE. See Fig. 14-34.

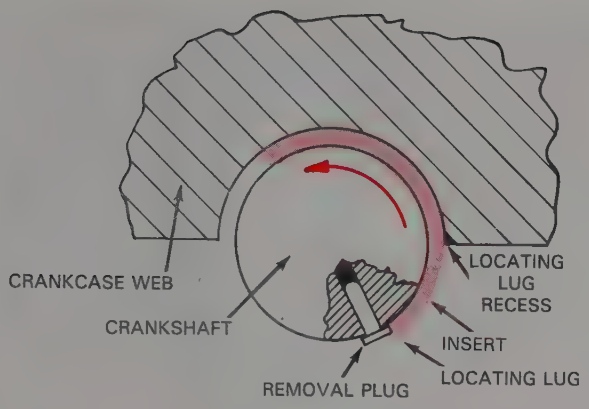


Fig. 14-34. Rolling a new insert into position.

Snap lower insert into cap. Lubricate and install. Run up snugly. Back off a few thousandths and remove front and rear main inserts. When installing the rear main upper insert, be careful the oil seal does not rotate out of position. When all inserts are in, torque all caps but the one with the thrust bearing. Align upper and lower flanges with crank thrust surface and torque cap. Bearing clearance should be checked with Plastigage.

CHECKING MAIN BEARING CLEARANCE—ENGINE IN CAR

Working on ONE bearing at a time, remove the cap. Wipe the journal and cap insert free of oil. With an extension jack, apply upward pressure to the crankshaft adjacent to the journal being checked. This will keep the shaft in contact with the upper insert so that the Plastigage will give a true reading. If the shaft is allowed to sag downward, the gauge material will be flattened when the cap is torqued, thus giving a false reading.

Place a strip of Plastigage across the lower insert, install cap, and torque. Remove and determine clearance by measuring flattened plastic.

INSTALLING CRANKSHAFT REAR MAIN BEARING OIL SEAL—ENGINE IN CAR

Some engines are designed so the rear main oil seal can be replaced without removing the shaft. Replacing these seals is often tricky and requires care.

Remove the cap. Pry out the old seal and clean groove. If a synthetic rubber seal is used, install in the cap at this time. Using a clean, brass drift punch, tap on end of the upper seal (it may help to rotate the shaft also) to shove the other end out. As soon as the end is clear, grasp it with pliers and remove. If it is a wick type and difficulty is encountered, it will help to drop the shaft a few thousandths. A corkscrew type attachment may be screwed into the end of the wick to help pull it out to a point where pliers can be used. Use care not to nick the journal seal surface.

Lubricate the new upper rubber seal and insert into groove. Push in, while rotating shaft in same direction, until seated.

In cases where a wick seal or packing is used, remove as previously described. To insert the new upper wick, attach a soft wire to one end, Fig. 14-35. Using the cap, preform the wick by installing in the cap groove. Do not cut off ends. Remove and lubricate wick thoroughly. Pass the wire up through and around the groove. Force the end of the wick into the groove. Tuck all fibers in and pull on the wire. Wiggle the wick where it enters the groove making sure the wick does not bulge out and hang up. Pull around until an equal amount protrudes from each side. Rotating the shaft will help. Cut the wick off flush. To prevent nicking the journal surface, a thin piece of shim stock can be slid between the end of the wick and the journal, Fig. 14-35.

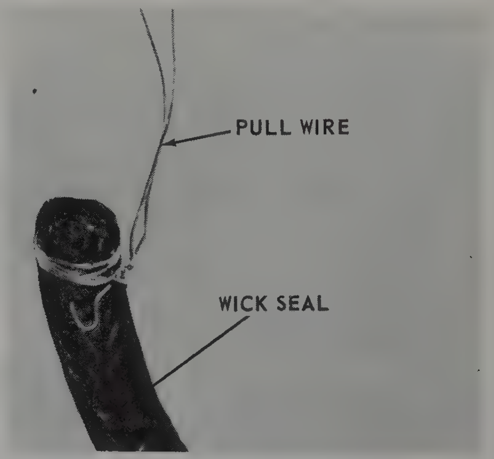


Fig. 14-35. Pull wire attached to wick type upper seal.

FLYWHEEL MOUNTING

The flywheel crankshaft flange surface must be clean and true. If dowel pins are used, align flywheel. Install cap screws and torque. If required, coat cap screw threads with oil resistant sealer. When needed, use lock washers or a lock plate. Some flywheels use a hardened plate that is intended to protect the flywheel against damage from the cap screw heads, Fig. 14-36.

If the clutch disc contact face is scored or wavy, it must be reground, Fig. 14-37.

CHECKING FLYWHEEL RUNOUT

Set up a dial indicator and rotate the flywheel. Force flywheel in one direction while turning to prevent end play from affecting reading. Determine runout by reading indicator. Check both clutch disc contact surface and rim edge, Fig. 14-38.

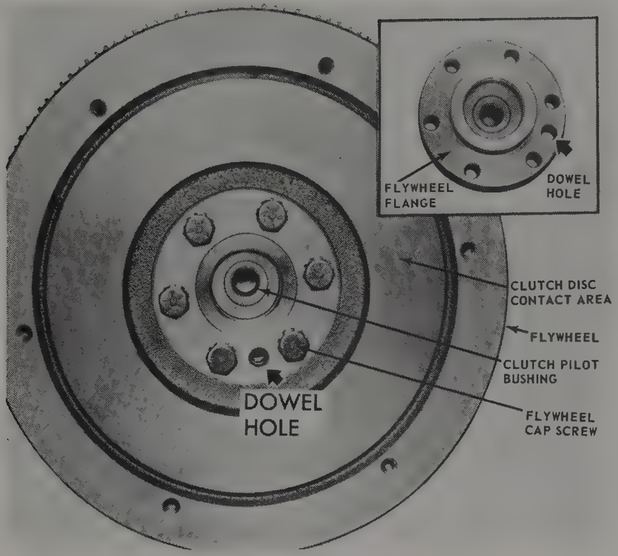

FLYWHEEL FLANGE
DOWEL HOLE
CLUTCH DISC CONTACT AREA
FLYWHEEL
CLUTCH PILOT BUSHING
DOWEL HOLE
FLYWHEEL CAP SCREW

Fig. 14-36. Flywheel aligned with dowel hole and bolted to flywheel flange. (G.M.C.)

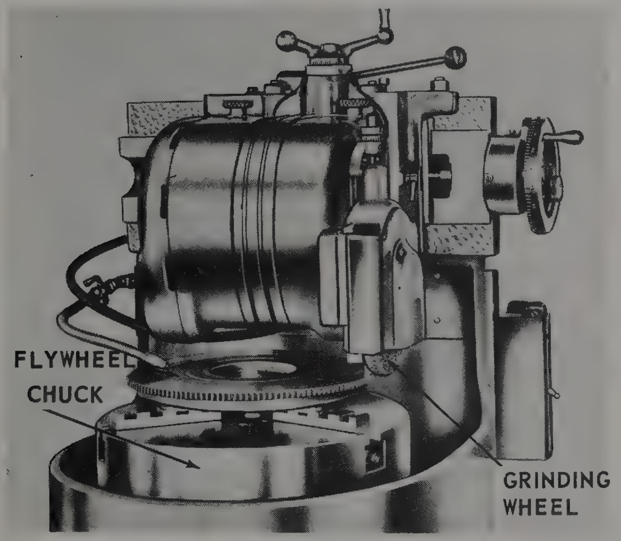

FLYWHEEL
CHUCK
GRINDING WHEEL

Fig. 14-37. Regrinding a flywheel clutch disc contact face. (Van Norman)

FLYWHEEL RING GEAR REPLACEMENT—(REMOVAL)

Some flywheel ring gears are shrunk in place. They are heated and placed in position. Upon cooling, they grasp the flywheel tightly. Others are welded and sometimes bolted into position.

If welded, the short welds can be cut, the old gear heated, and driven from the flywheel.

Ring gears utilizing a shrink fit can also be heated (keep heat away from flywheel) and removed. The ring gear can also be drilled almost through. A chisel can then be used to spread it enough for removal. When driving the gear off, DO NOT STRIKE THE FLYWHEEL.

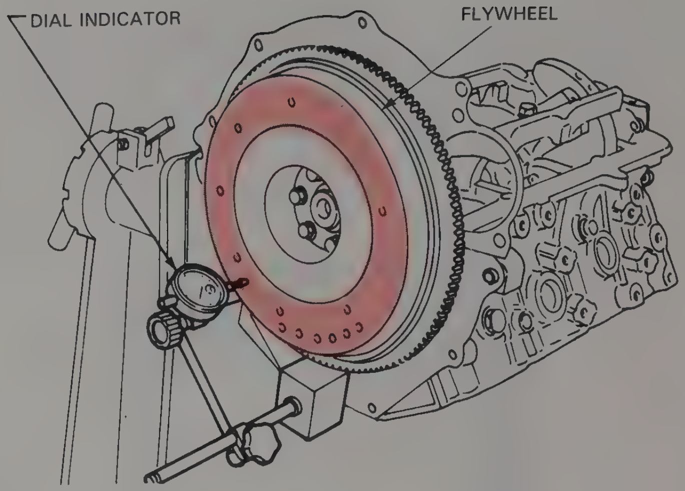

DIAL INDICATOR
FLYWHEEL

Fig. 14-38. Checking flywheel clutch disc contact surface runout with dial indicator. (Nissan)

RING GEAR INSTALLATION

The gear, if a shrink fit is used, should be heated (DO NOT EXCEED 450°F or 232°C). A controlled temperature oven is ideal. If none is available, the gear can be heated in oil. Use a thermometer and keep gear from touching the bottom of the tank. COVER TANK WHILE HEATING TO AVOID FIRE. Another method involves placing the gear on a fire brick surface and heating with an acetylene torch. Move the flame around the ring. Wire solder (50/50 or 40/60 type) is touched against the ring frequently as the temperature is raised. When the solder will start to melt when touched firmly against the ring, the temperature is high enough. The 50/50 (50 percent tin, 50 percent lead) melts at 414°F (212°C). The 40/60 (40 percent tin, 60 percent lead) melts at 460°F (238°C). DO NOT OVERHEAT THE RING AS THE TEETH WILL BE SOFTENED.

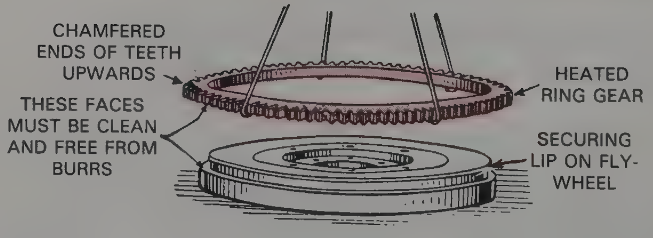

CHAMFERED ENDS OF TEETH UPWARDS
THESE FACES MUST BE CLEAN AND FREE FROM BURRS
HEATED RING GEAR
SECURING LIP ON FLYWHEEL

Fig. 14-39. Lowering the heated ring gear onto the flywheel. Asbestos gloves would permit hand holding the ring.

When hot, quickly place over the flywheel contact surface and immediately drive into place. Chilling the flywheel helps. Be sure the ring is placed so the relieved edge of the teeth (if so designed) face in the desired direction, Fig. 14-39.

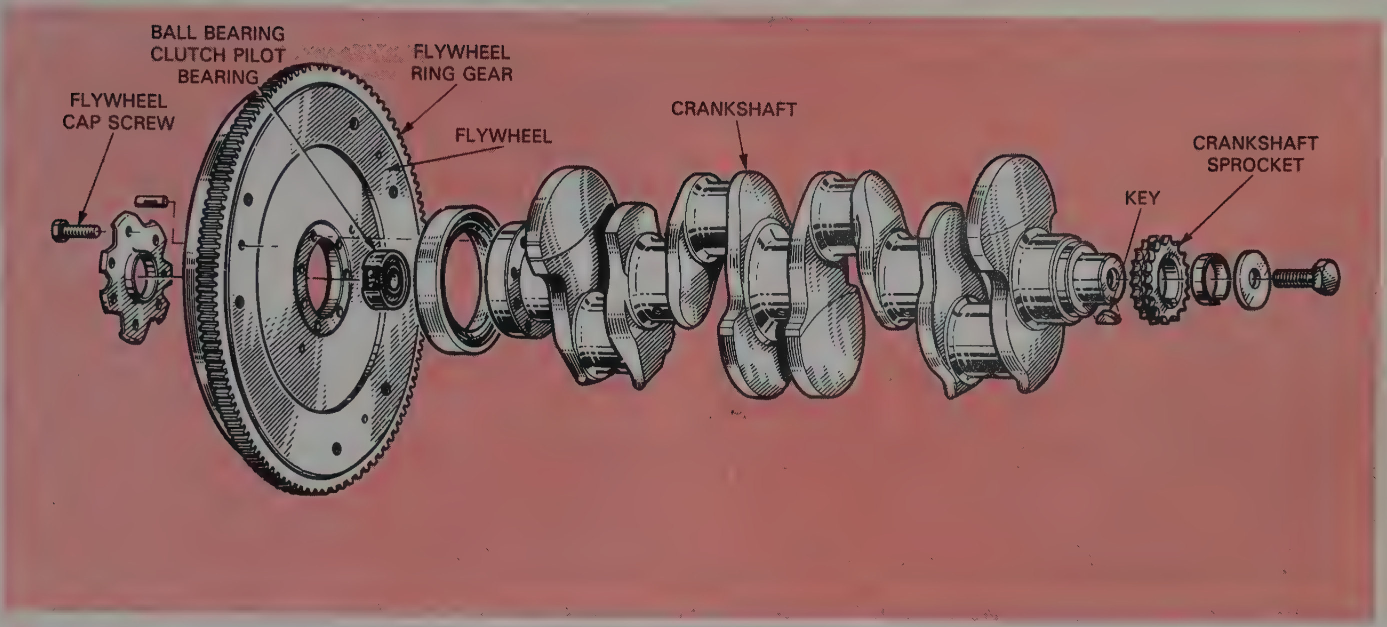

BALL BEARING CLUTCH PILOT BEARING
FLYWHEEL RING GEAR
FLYWHEEL CAP SCREW
FLYWHEEL
CRANKSHAFT
CRANKSHAFT SPROCKET
KEY

Fig. 14-40. Crankshaft and flywheel assembly used in one type of four cylinder engine. Note ball bearing pilot bearing. (Renault)

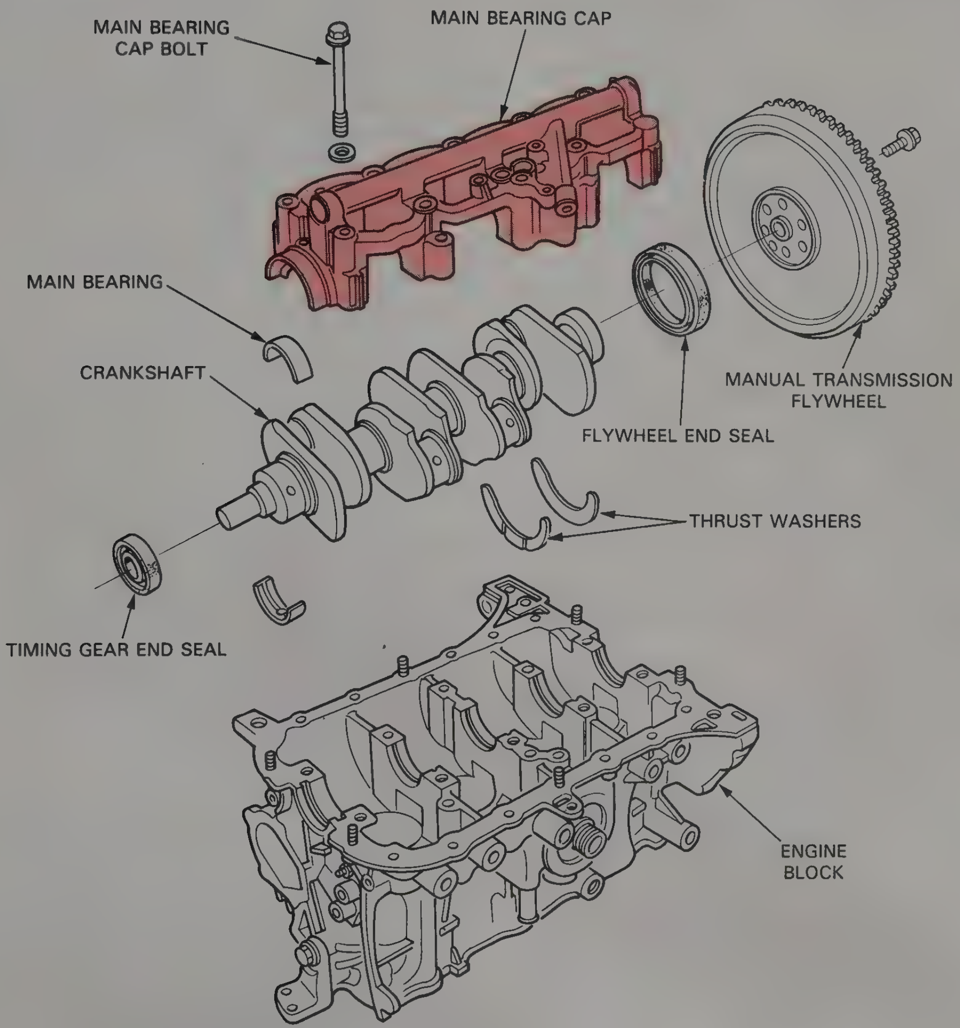

MAIN BEARING CAP BOLT
MAIN BEARING CAP
MAIN BEARING
CRANKSHAFT
MANUAL TRANSMISSION FLYWHEEL
FLYWHEEL END SEAL
THRUST WASHERS
TIMING GEAR END SEAL
ENGINE BLOCK

Fig. 14-41. This engine uses a one-piece main bearing cap. It houses machined areas for individual inserts. (Honda)

A complete crankshaft-flywheel assembly is pictured in Fig. 14-40. Fig. 14-41 shows an engine using a one-piece main bearing cap.

SUMMARY

Mark bearing caps before removal. Remove by LIGHT tapping and prying.

Remove crank carefully and place where journals will not be damaged.

With caps in place and torqued, check main bearing bores for distortion and alignment. Bore out-of-roundness and alignment can be corrected by align boring; either undersize bearings or the bores themselves.

Clean crankshaft thoroughly. Oil lightly.

Check finish and accuracy of all journals. Journals must be smooth and free of excessive taper, out-of-roundness, and overall wear.

Check crankshaft alignment with V-blocks and a dial indicator. Support properly. Runout should not exceed .002 in. (0.05 mm) overall.

Crankshafts can often be straightened by bending or through the use of heat.

Out-of-roundness, taper, and wear can be corrected by grinding. Following grinding, all journals and fillets should be polished to produce a surface finish of 16 micro inches or smoother. Severely damaged journals will have to be built up prior to grinding. Undersizing journals in excess of .030 in. (0.76 mm) is often questionable.

Store crankshaft on end or support properly to prevent set.

Bearing inserts must have proper spread and crush. They must be clean, oiled, and snapped into a clean bore. They must be of the exact size required. Be sure oil holes are aligned and that the locating lugs are in the recess. Check bearing clearance with Plastigage. If the engine is in the car, push up on the crank before checking.

Rear main oil seals must be carefully installed. Use a thin coating of gasket cement between the cap and block parting surfaces.

When installing main bearing caps, align the thrust bearing upper and lower halves with the crankshaft thrust surface. Torque all caps. Marks on cap and crank web must align. Check crankshaft end play.

When measuring main journals with the engine in the car, use special gauge or an outside micrometer with caliper type jaws.

To remove and install upper main inserts with the engine in the car, use special removal plugs.

Rear main seal upper halves can often be installed with the crank in place by pulling or forcing the seal around in the groove.

Flywheel mounting surface and crankshaft flange must be clean and free of burrs. Torque flywheel cap screws and use locks where needed. Check flywheel runout.

Flywheel ring gears may be removed and installed by heating. Never exceed 450°F (232°C). Install ring with teeth pointing in the correct direction. Tack weld if required.

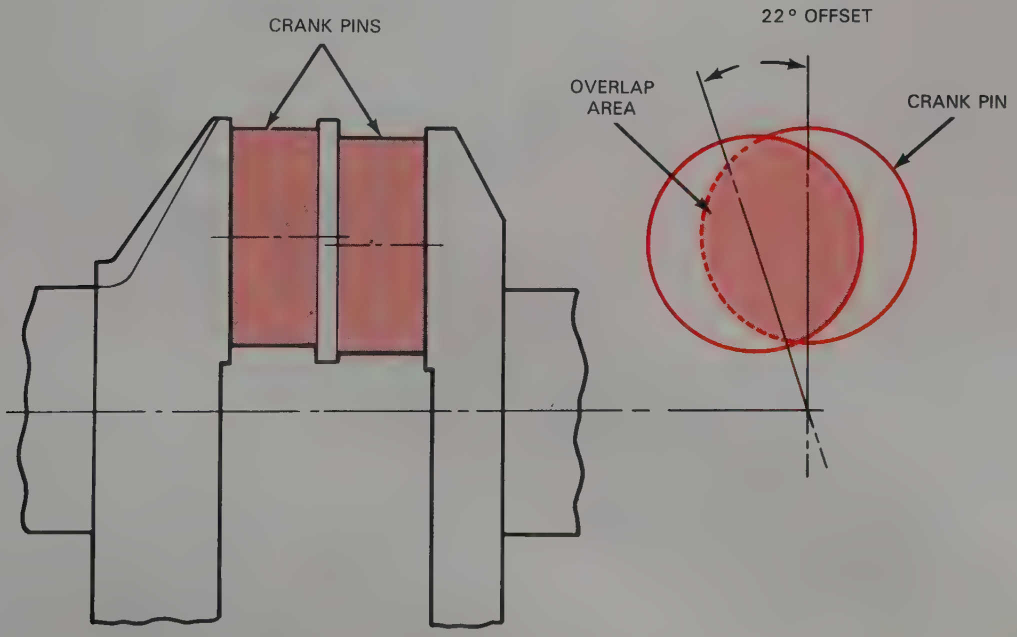
KNOW THESE TERMS

Vibration damper, Main bearing cap, Crankcase web, Bore misalignment, Crocus cloth, Connecting rod journal, Fillet radius, Undersize insert, Asbestos wick seal, Synthetic seal, Crankshaft micrometer, Insert removal plug, Flywheel runout, Ring gear, Crankshaft sling, Bore alignment, Aligning bar, Journal taper, Counterweight, Oil slinger, Crankshaft thrust face, Journal polishing, Crankshaft sprocket, Micro inch, Insert thrust flange.

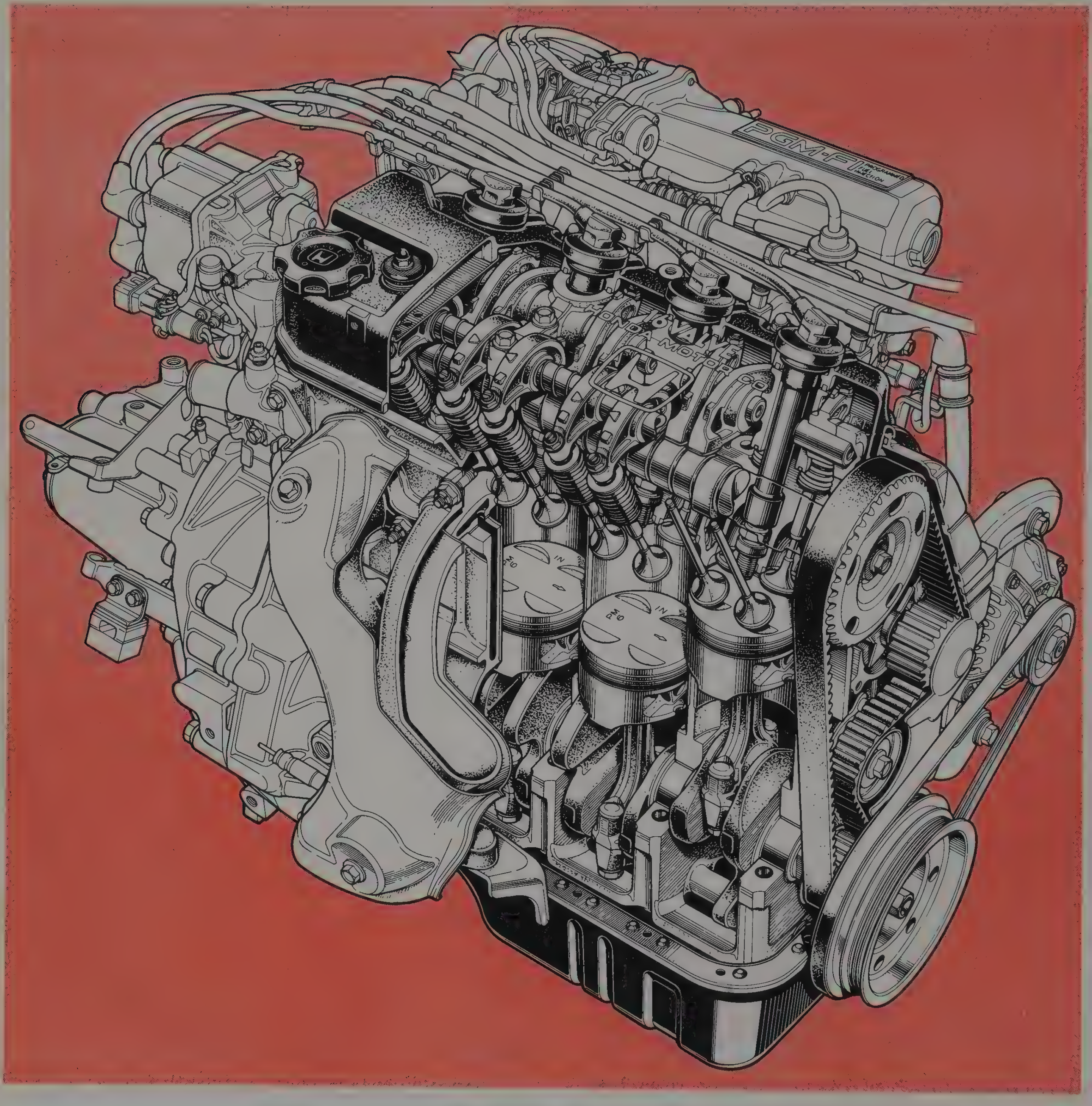
QUIZ - Chapter 14

1. Prior to removal, main bearing caps should be:
   a. Carefully studied.
   b. Tapped lightly with a rawhide hammer.
   [✓ c.] Marked.
   d. Thoroughly washed.
2. Bearing caps are rugged and may be pounded on, if necessary, to remove. True or [✓ False]?
3. Bearing bores should not show out-of-roundness in excess of:
   a. .0001 in. (0.0025 mm).
   [✓ b.] .0015 in. (0.0381 mm).
   c. .007 in. (0.18 mm).
   d. .0150 in. (0.38 mm).
4. If the crankshaft is out of alignment, the inserts will show this wear pattern:
   a. Intermediate journal inserts with the most wear.
   [✓ b.] End journals with the most wear.
   c. All journals worn equally.
   d. Every other journal worn.
5. Bearing bore misalignment should not exceed .0015.
6. Crankshaft alignment must be held within .002 overall.
7. Crankshaft journals must not be tapered over:
   a. .005 in. (0.13 mm).
   b. .0001 in. (0.0025 mm).
   c. .010 in. (0.25 mm).
   [✓ d.] .001 in. (0.025 mm).
8. Maximum journal out-of-roundness should not exceed .001.
9. For an acceptable journal finish, the micro inch finish should be:
   a. 100 micro inch.
   b. 1 micro inch.
   [✓ c.] 16 micro inch.
   d. 160 micro inch.

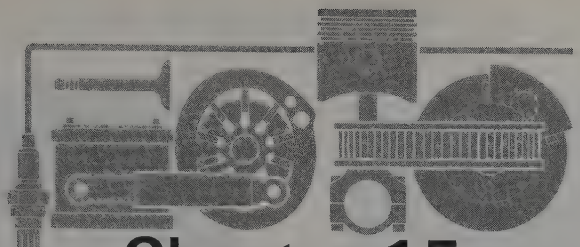
10. When measuring journals, they should be checked in several spots, near both ends. [✓ True] or False?
11. In measuring a journal in four places on end A, you have readings of 2.8950, 2.8960, 2.8980, 2.896. On end B, the readings are 2.8935, 2.8945, 2.8960, 2.8945. STANDARD for the journal is 2.900. List the correct figures for:
    a. Maximum wear________________.
    b. Minimum wear________________.
    c. Taper________________.
    d. Out-of-roundness________________.
12. The journal in question eleven must be ground. [✓ True] or False?
13. Will an undersize bearing work on this journal? Yes ___yes___, No ________. If so a ________undersize is required. (Standard is 2.900. Maximum measurement is 2.899. Minimum measurement is 2.8987.)
14. Damaged journals, too far gone to regrind, can often be saved by ___welding___ or ___spraying___ and then grinding.
15. Small nicks can be smoothed down to the shaft surface with ___crocus___ cloth.
16. Store crankshafts ___stand___ ___up___ or properly support.
17. All insert sets have both upper and lower shells drilled for oil entry. True or [✓ False?]
18. File off bearing crush. True or [✓ False?]
19. Bearing clearance is best checked with ___plastic gage___
20. List three ways oil can pass by the rear main bearing. throught flywheel housing flage bolt
21. Name two materials often used for rear main bearing seals. asbestos neophreene
22. When installing the wick type seal:
    [✓ a.] Trim the ends flush with the parting surface.
    b. Let the excess protrude.
    c. Lay the excess across the parting surface.
    d. Drive the excess down into the groove.
23. When the engine is in the car, the upper inserts can best be removed by:
    a. Blowing out with air pressure.
    b. Driving out with a punch.
    [✓ c.] Rolling out with a removal plug.
    d. Pulling out with a wire.
24. Upper and lower insert thrust flanges automatically align when the cap is torqued. True or [✓ False?]
25. Crankshaft main bearing journals can be measured with the shaft in the engine. [✓ True] or False?
26. It is important to check flywheel runout. [✓ True] or False?
27. Some flywheel ring gears are secured by short arc welds. [✓ True] or False?
28. Some rear shaft seals are constructed so that oil resistant ___seal___ must be applied to the cap screw threads.
29. When installing a new flywheel ring gear, never heat above:
    a. 200 °F (93 °C).
    b. 900 °F (482 °C).
    c. 650 °F (343 °C).
    [✓ d.] 450 °F (232 °C).
30. Undersize, semifinished bearings are designed to be installed and:
    [✓ a.] Bored to size.
    b. Sanded or ground to size.
    c. Worn to size by the shaft rotation.
    d. Burnished to size.



Overlap area of crank pin provides additional strength. (Chrysler)


PGM-FI
PROGRAMMED
FUEL
INJECTION
IN
IN

Cutaway view of a 1.6-liter, four-cylinder, single overhead camshaft (SOHC), 16-valve engine. This engine uses multi-point, programmed fuel injection. The engine produces 108 horsepower at 6000 rpm and 100 ft.-lbs. of torque at 5000 rpm. (Honda)



Chapter 15

CAMSHAFT, TIMING GEAR, CHAIN, AND BELT SERVICE

After studying this chapter, you will be able to:

☐ Properly remove and install a vibration damper.
☐ Measure timing gear and chain wear.
☐ Remove and install camshaft gears and sprockets.
☐ Inspect a camshaft and its drive mechanism for problems.
☐ Service a front cover oil seal.
☐ Remove and install a timing belt.
☐ Service camshaft bearings.

AN IMPORTANT AREA

The condition of the timing gears, chains, belts, and sprockets, as well as the camshaft and camshaft bearings, is sometimes ignored during engine overhaul. To neglect these areas, despite the relative long service life of the parts concerned, is extremely POOR PRACTICE.

Worn gears, chains, belts, and sprockets will alter valve timing and can cause damaging camshaft torsional vibration. Engine overheating, accelerated wear, and sluggish operation can result. Accurate valve lash settings are impossible and with advanced wear, objectional noise will appear.

Worn camshaft bearings can seriously lower oil pressure plus producing excessive throw off that will increase oil consumption. Other vital engine bearings will be starved and deposits (carbon) in the combustion chambers can build to dangerous levels. Worn, galled, or chipped cams will lower valve lift and damage lifters.

The camshaft and related parts make up a vital area of the engine and as such, should receive careful attention.

VIBRATION DAMPER REMOVAL

Remove the retaining cap screw in the end of the crankshaft, if used. Remove any bolt-on pulleys. Attach a suitable puller to the damper HUB (do not pull on the outer rim) and withdraw the damper (sometimes referred to as harmonic balancer), Fig. 15-1.

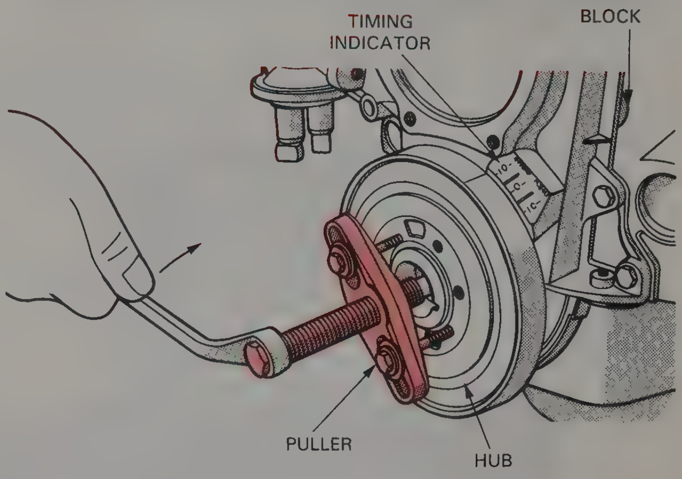


Fig. 15-1. Pulling a vibration damper. Pulling force is applied to center hub. (Dodge)

DO NOT RUIN CRANKSHAFT THREADS

When running the puller screw against the hollow end of the crankshaft, be careful not to damage the crankshaft threads. If the puller screw is not large enough to avoid entering the threaded hole, place a cap over the end of the crankshaft, Fig. 15-2.

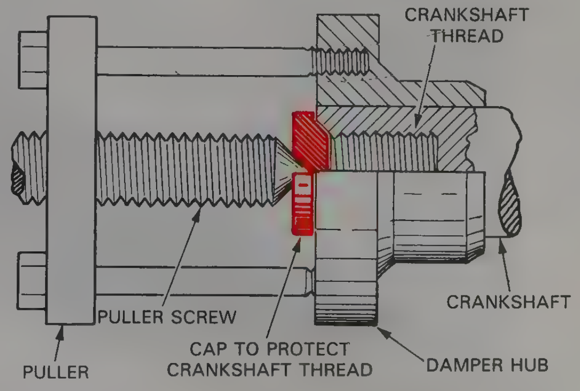


Fig. 15-2. Protect crankshaft thread by using a suitable plug.

REMOVE TIMING COVER

Remove the timing gear, chain, or belt cover. Watch for variations in cap screw lengths. If possible, leave water pump in place.

CHECKING TIMING GEAR WEAR

Visually inspect both camshaft and crankshaft gears. If obviously worn, chipped, or galled, gears must be replaced. If they LOOK good, check the backlash (distance one gear will rotate without moving other gear). Backlash can be checked with a dial indicator or by using a narrow blade feeler gauge.

CHECKING TIMING GEAR BACKLASH WITH FEELER GAUGE

Select a feeler gauge that exceeds the maximum permissible backlash by .001 in. (0.025 mm). Rotate the camshaft gear firmly against the crankshaft gear. While holding it in this position, try to insert the feeler on the free side of the teeth. If the feeler will not enter, try in several other positions, Fig. 15-3.

When checking backlash in NEW GEARS, check for MINIMUM as well as MAXIMUM backlash. Always check in several spots around the gear.

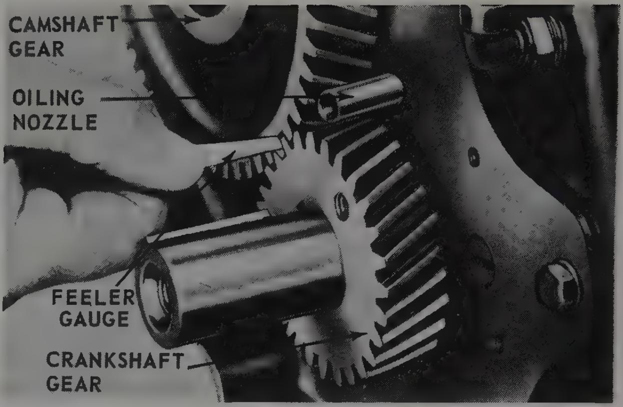


Fig. 15-3. Using a feeler gauge to check backlash between gear teeth. (Chevrolet)

In the event new gears will not meet MAXIMUM specifications, timing gears are sometimes available in .001, .002, and .003 in. (0.025, 0.05, 0.08 mm) oversize.

CHECKING BACKLASH WITH DIAL INDICATOR

Set up the indicator so the stem engages the side of a tooth on the timing gear. Align the indicator so the stem is parallel to the direction of tooth travel.

Rotate the camshaft gear back and forth (do not

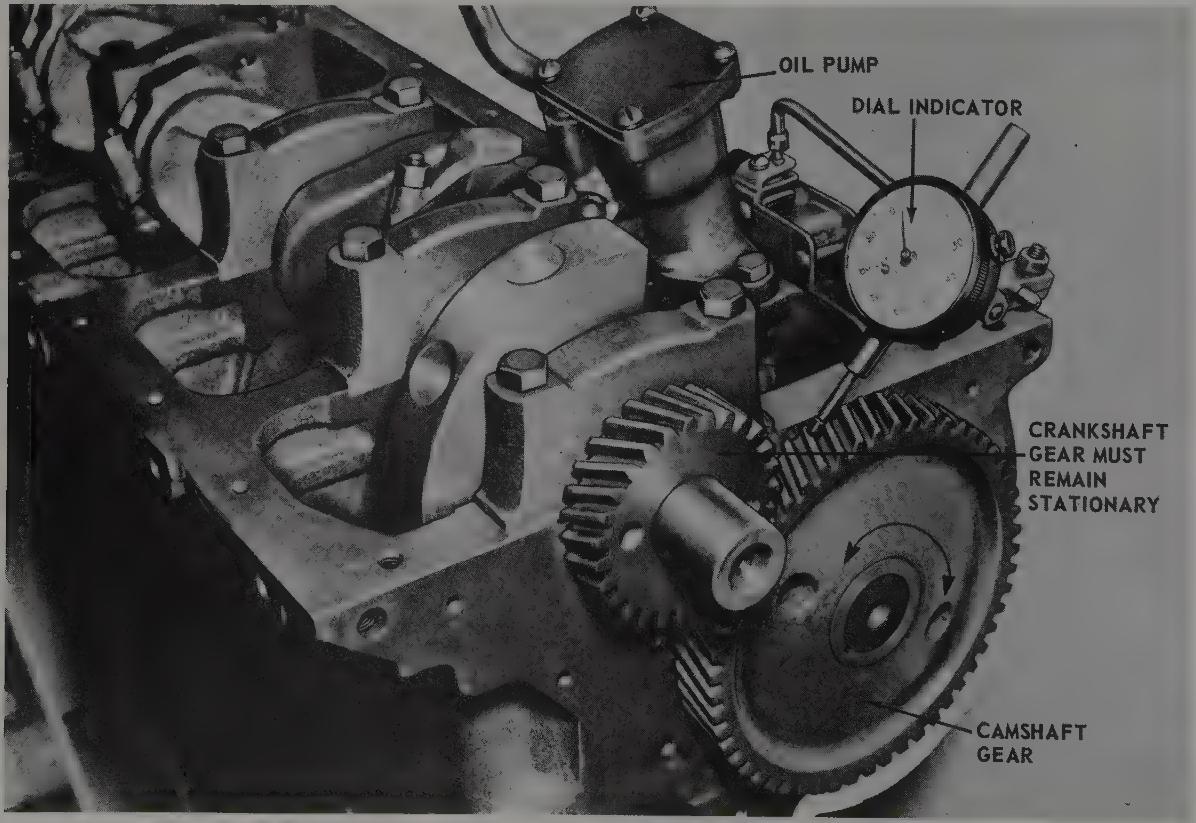


Fig. 15-4. Checking gear backlash with dial indicator. Make certain indicator stem parallels direction of tooth movement. (G.M.C.)

move the crankshaft gear) over the full backlash range. Observe the dial indicator reading. Check the gear in several different spots around its circumference, Fig. 15-4.

CORRECT BACKLASH IS A MUST

The effects of excessive backlash have been mentioned. INSUFFICIENT backlash will cause noise, galling, and chipping.

Align boring either or both crankshaft and camshaft bearings can alter the distance between centers, thus aggravating backlash settings.

Normal backlash specifications are around .004-.006 in. (0.102-0.15 mm) with about .010 in. (0.25 mm) considered the absolute maximum. Minimum backlash should be .003 in. (0.08 mm). REMEMBER THAT NEW GEARS WILL NOT NECESSARILY PRODUCE CORRECT BACKLASH. ALWAYS CHECK BACKLASH AT SEVERAL POINTS - CAREFULLY.

CHECK GEAR RUNOUT

Set up the dial indicator so that the stem engages the outer front face of the gear. Rotate the gear while forcing it against the thrust plate. Check the indicated runout. Maximum runout should be around .004 in. (0.102 mm) for the camshaft gear. Check the runout of the crank gear also.

REPLACE BOTH GEARS

When replacing the camshaft timing gear, it is considered good practice to also replace the crankshaft gear. A worn crankshaft gear will not engage the new cam gear perfectly and will cause premature wear.

REMOVING CAMSHAFT GEAR

Some camshaft gears are bolted in place and removal is simple. Others however, are force fit on the camshaft and are best pressed off. Turn the cam gear so that the thrust plate (when used) retaining cap screws are accessible. Remove the cap screws, Fig. 15-5.

Pull the camshaft from the engine being careful to avoid damage to the camshaft bearings.

Before the camshaft can be pulled, the distributor or oil pump (depending on which one has gear), fuel pump, and valve lifters must be removed. Mushroom type lifters that must be removed from below, should be pulled up and secured with clamps to hold them out of the way.

Using a setup similar to that shown in Fig. 15-6, press the gear from the shaft. Hold the camshaft so it will not drop and be damaged.

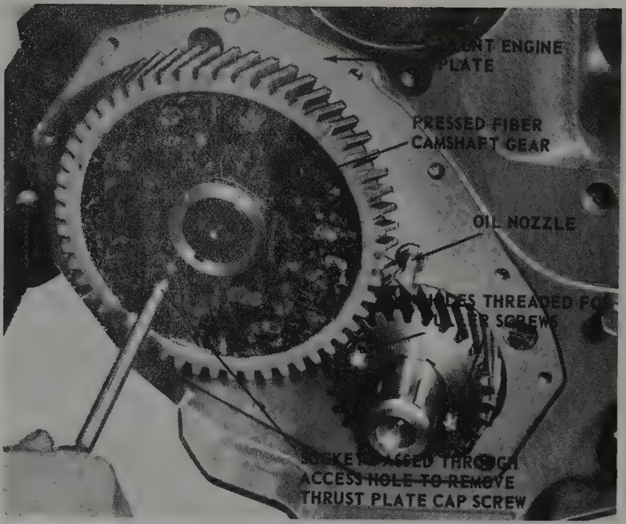


Fig. 15-5. Removing camshaft thrust plate cap screws.

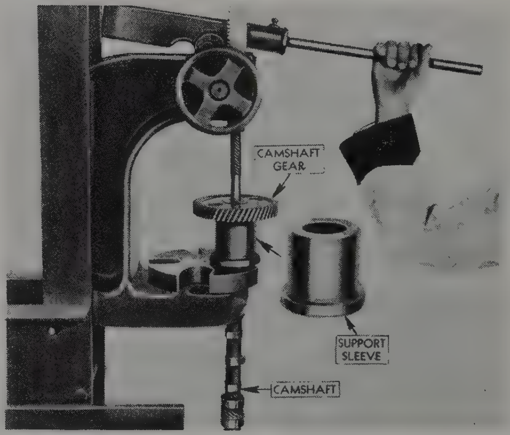


Fig. 15-6. An arbor press is handy for pressing off timing gear. Support sleeve must bear against gear hub.

INSTALLING A NEW CAMSHAFT GEAR

Clean the gear engagement area thoroughly. Lubricate lightly. Slide a NEW spacer and thrust plate in place. Face them in the correct direction. Drive in Woodruff key. Set up the camshaft in press (support shaft under front bearing journal edge) and press timing gear all the way on. The spacer will stop the gear and insure correct end play, Fig. 15-7.

Apply pressure to the steel HUB only. DO NOT FORGET TO INSTALL THE WOODRUFF KEY.

CAMSHAFT CHECKS

Camshaft alignment and condition checks will be discussed later in the chapter. These checks would obviously be done prior to installing the camshaft.

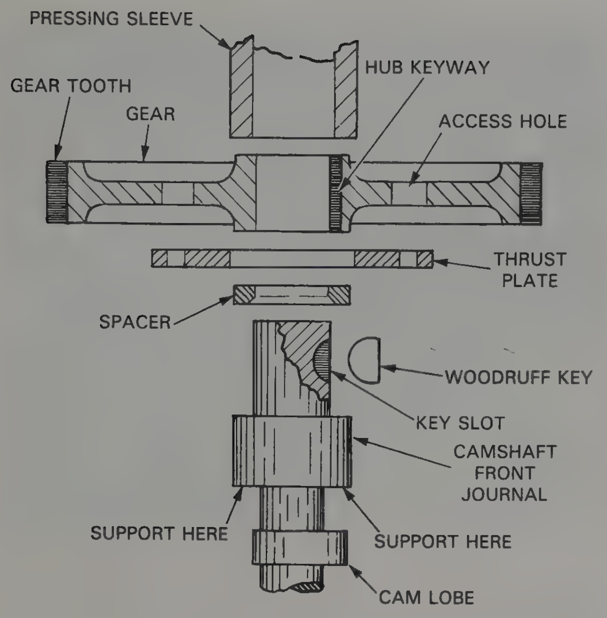

PRESSING SLEEVE
GEAR TOOTH
GEAR
HUB KEYWAY
ACCESS HOLE
THRUST PLATE
SPACER
WOODRUFF KEY
KEY SLOT
CAMSHAFT FRONT JOURNAL
SUPPORT HERE
SUPPORT HERE
CAM LOBE

Fig. 15-7. Part arrangement for typical pressed-on camshaft gear.

CHECK END PLAY AT THRUST PLATE

After the gear is pressed on, use a feeler gauge to check clearance (end play) between the thrust plate and the face of the camshaft journal. See Fig. 15-8. A dial indicator can also be used.

CRANKSHAFT TIMING GEAR REMOVAL

If the crankshaft gear is to be removed, do so at this time. If there are no threaded holes for puller bolts (as in Fig. 15-5), use a puller setup as shown in Fig. 15-9. Be careful not to burr the gear teeth during pulling.

REPLACE THE CRANKSHAFT GEAR BEFORE CAMSHAFT AND GEAR ARE INSTALLED

Clean the end of the crankshaft and lubricate. Make certain ALL Woodruff keys are in place. The forward key often has a tapered end to facilitate aligning the crankshaft gear and damper. Make sure it faces forward.

Install the crankshaft gear with the timing mark, Fig. 15-10, facing outward. Drive the gear fully into place with a suitable sleeve and heavy hammer. DO NOT MAR THE TEETH.

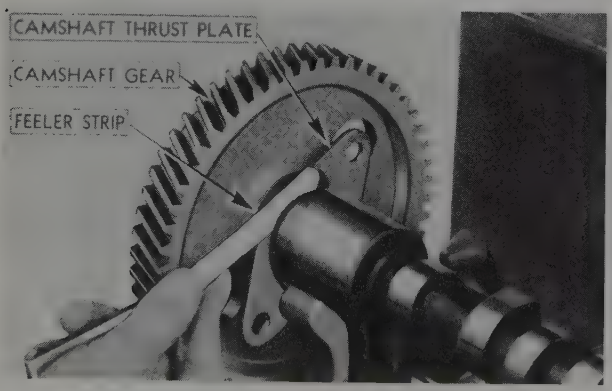

CAMSHAFT THRUST PLATE
CAMSHAFT GEAR
FEELER STRIP

Fig. 15-8. Measuring end play clearance with feeler gauge. (G.M.C.)

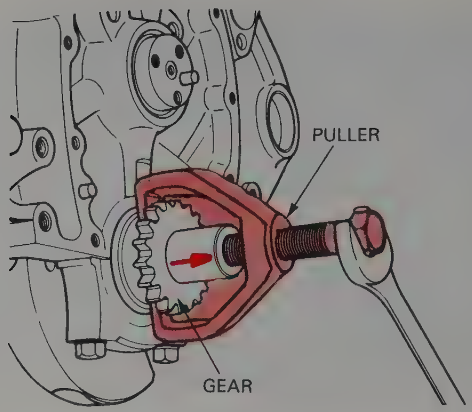

PULLER
GEAR

Fig. 15-9. Pulling crankshaft gear. (Chevrolet)

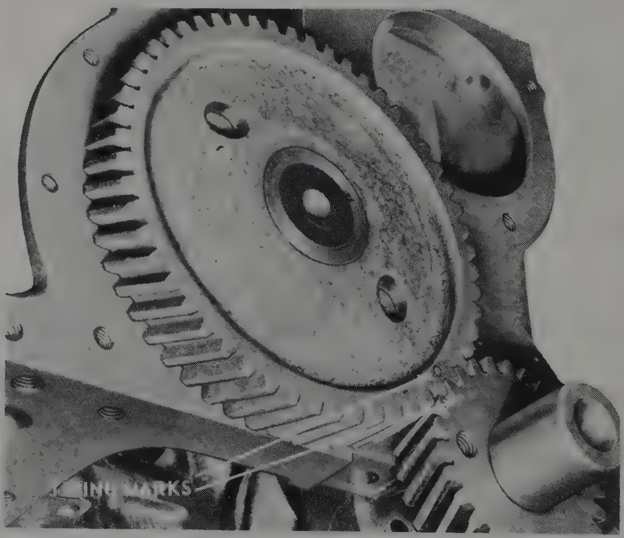

TIMING MARKS

Fig. 15-10. Be certain timing marks are properly aligned.

INSTALLING CAMSHAFT AND GEAR

Turn the crankshaft so the timing mark faces the center of the front cam bearing. Lubricate the cam bearing journals and lobes. Slide the camshaft carefully into position making certain the camshaft gear timing mark is aligned with the crank gear mark, Fig. 15-10.

Install the thrust plate cap screws (use new locks) and torque to specifications. Check for correct backlash and runout and then lube gears thoroughly. Gears must be properly aligned with each other (tooth engagement across full gear width).

REMOVING TIMING GEAR - CAMSHAFT IN ENGINE

It is possible to remove and replace the pressed-on camshaft gear without removing the camshaft.

The pressed fiber gear is broken from the hub with a hammer and chisel. Using a SHARP chisel, split the hub over the Woodruff key. Remove hub and thrust plate. Install a new spacer and thrust plate. Before driving the new gear into position, the camshaft MUST BE BLOCKED IN THE FULL FORWARD POSITION. Failure to do this will allow the shaft to move backward into the block far enough to loosen the rear cam bearing plug. This would result in severe oil leakage into the flywheel housing area.

Several special tools are available for this blocking process. The tool can be inserted between a cam lobe and a cam journal bearing web. The gear is then driven on (drive on steel hub only). As the gear goes on, turn the crankshaft slowly to prevent binding between gear teeth. Turn in a clockwise direction.

TIMING CHAIN AND SPROCKET SERVICE - CHECKING CHAIN FOR WEAR

Place a steel rule against the block as shown in Fig. 15-11. Turn the camshaft sprocket clockwise as far as it will go (crankshaft must not turn). Align one of the chain link pins with a mark on the scale. Without moving the scale, or the crankshaft, turn the gear counterclockwise as far as possible. Note the distance the link pin has moved and check against manufacturer's specifications. See Fig. 15-11.

Another technique involves turning the crankshaft so all slack is taken up on one side. Carefully measure from the tightened chain surface (about midpoint) to a reference point. Rotate the crankshaft in the opposite direction to produce all possible slack on the same side. Pull the slack chain outward toward the reference point as far as possible. While holding the chain out, measure from the surface to the reference point. The difference in the two measurements should, in general, not exceed ONE-HALF INCH (12.7 mm). A new chain, on new sprockets, will have about 1/4 in. (6.35 mm) of slack, Fig. 15-12.

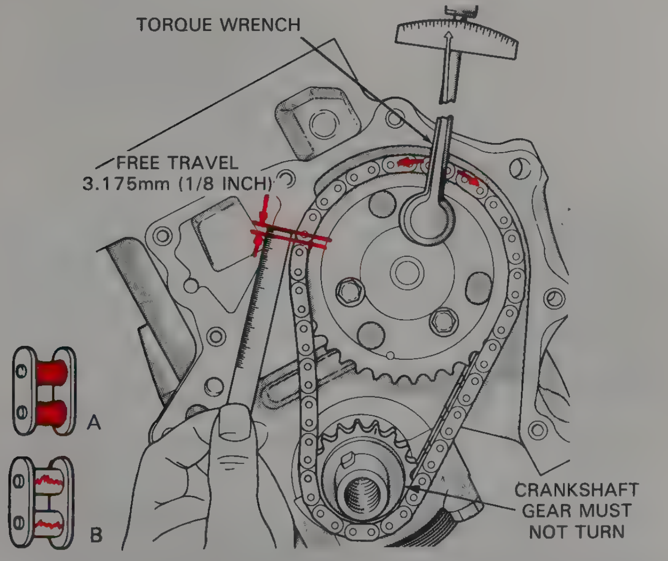


Fig. 15-11. Checking timing chain wear by measuring sprocket free travel. A—Wear on link. B—Link cracked. (Dodge and Nissan)

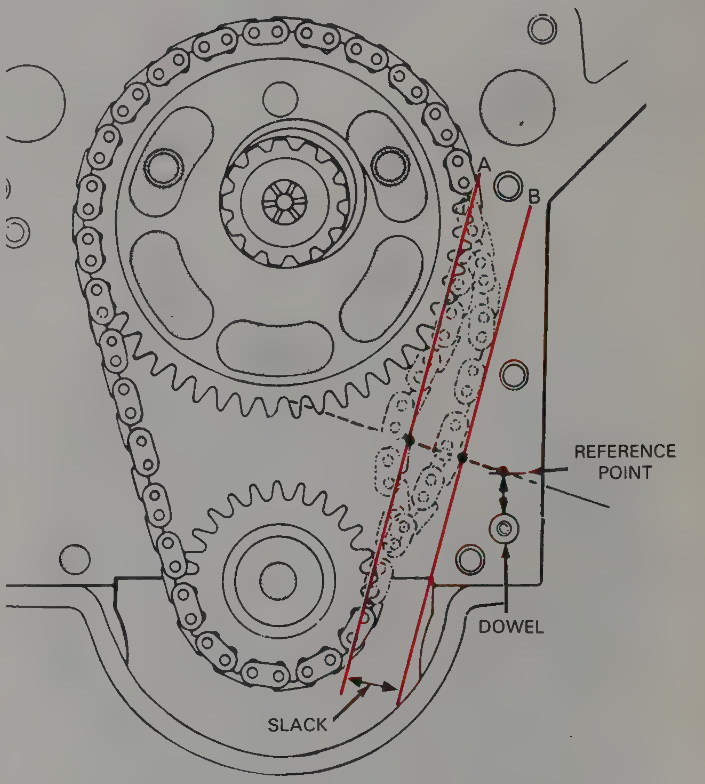


Fig. 15-12. Timing chain wear can be checked by measuring slack. The distance between lines "A" and "B" represents the amount of slack in the chain. (Jeep)

There also are special spring-loaded timing chains that have no slack, Fig. 15-13.

LONG CHAINS FOR OVERHEAD CAMSHAFTS

Some overhead camshaft engines use long timing chains or timing belts. Slack is controlled by idler sprockets, rubbing blocks, or spring-loaded tensioning devices, Fig. 15-13.

TIMING CHAIN REMOVAL

Crank the engine until the timing marks on both sprockets face each other, and are aligned with a line between the center of the crankshaft and camshaft. To

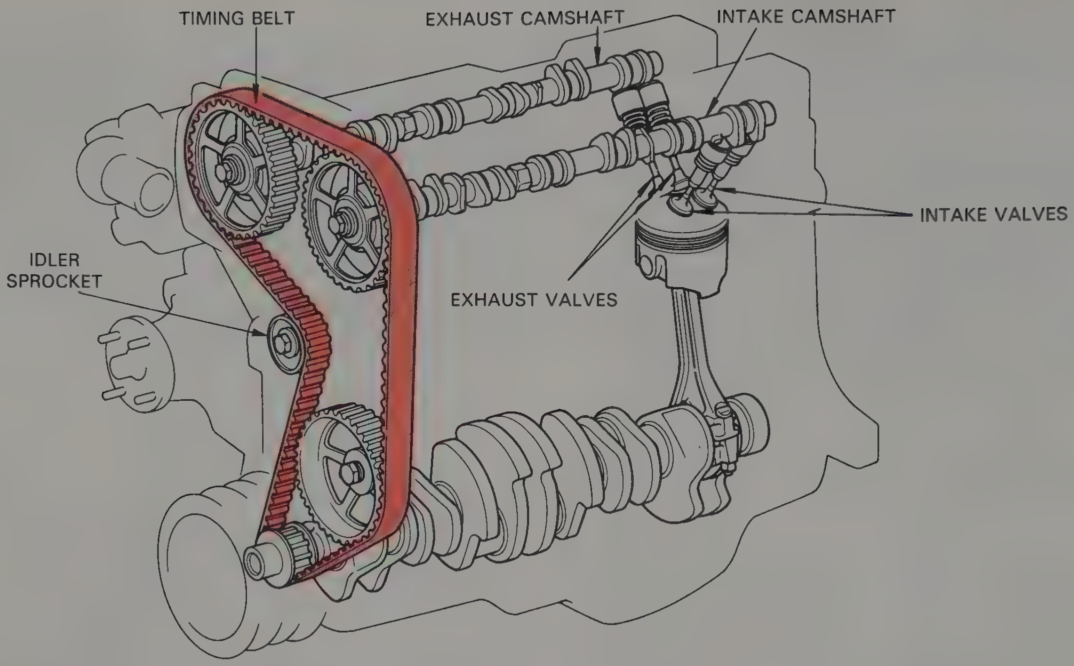

TIMING BELT
EXHAUST CAMSHAFT
INTAKE CAMSHAFT
INTAKE VALVES
IDLER SPROCKET
EXHAUST VALVES

Fig. 15-13. Dual overhead camshafts driven by timing belt. (Toyota)

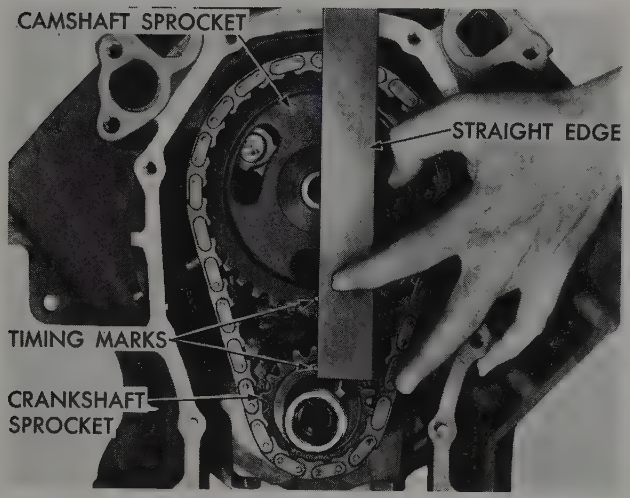

CAMSHAFT SPROCKET
STRAIGHT EDGE
TIMING MARKS
CRANKSHAFT SPROCKET

Fig. 15-14. Align timing marks with shaft centers before removing chain and sprockets. (Plymouth)

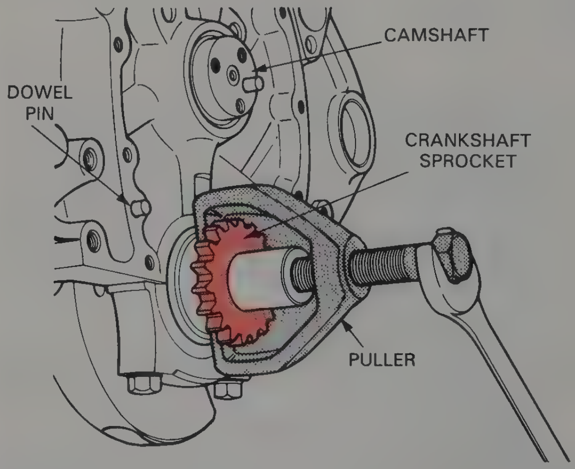

CAMSHAFT
DOWEL PIN
CRANKSHAFT SPROCKET
PULLER

Fig. 15-15. Pulling crankshaft sprocket. Note dowel pins used to align chain cover. (Chevrolet)

facilitate sprocket and chain installation, do not rotate the crankshaft until chain and sprockets are replaced. Look at Fig. 15-14.

Remove the camshaft sprocket-to-camshaft cap screws. These same cap screws are often used to retain a fuel pump eccentric and in some cases, a distributor drive gear.

Work both sprockets forward (two large screwdrivers will work) until the camshaft sprocket is clear. On some installations, the cam sprocket will clear without removing the crank sprocket.

Remove the crankshaft sprocket from the crankshaft. Use a puller if needed, Fig. 15-15.

INSPECT SPROCKETS

Carefully inspect both sprockets for signs of wear or chipping. The slightest indication of wear is ample cause for rejection. Look for shallow chain imprints on the sprocket teeth, Fig. 15-16.

CHECK THRUST PLATE WEAR

If a thrust plate is used, check it for signs of excessive wear. Replace if necessary.

NEW SPROCKETS ARE GOOD INVESTMENT

When installing a NEW timing chain, best practice is to use NEW sprockets. Worn sprockets will increase

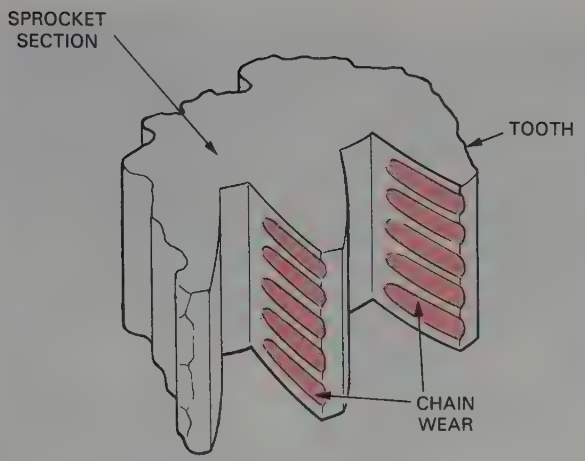


Fig. 15-16. Sprocket which shows wear. This sprocket is ready for scrap pile.

the wear rate on the new chain as well as the sprockets themselves.

CHAIN AND SPROCKET INSTALLATION

If the camshaft sprocket can be removed and replaced without disturbing the crank sprocket, drive the crank sprocket fully into place, Fig. 15-17.

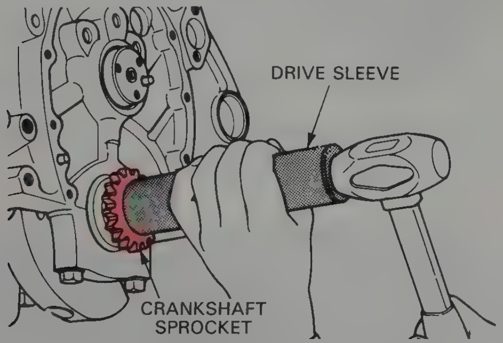


Fig. 15-17. Driving crankshaft sprocket into place. (Chevrolet)

When both sprockets must go on together, face the timing marks toward each other, away from the engine. Place the chain around the sprockets. Slip the crankshaft sprocket onto the crank until the cam sprocket touches the camshaft. At this point, make certain the timing marks are together and in line with the center of the crankshaft and the camshaft. Refer to Fig. 15-18.

Use the attaching cap screws to pull the cam sprocket into place. DO NOT HAMMER IT ON AS THE REAR OIL SEAL PLUG (WELCH PLUG, CORE HOLE PLUG) COULD BE LOOSENED.

Make sure the fuel pump eccentric or distributor drive, if used, is in place. Torque cap screws. Make a final timing mark alignment check. Install the crankshaft oil slinger and check sprocket runout, chain slack, and camshaft end play. Look at Fig. 15-19.

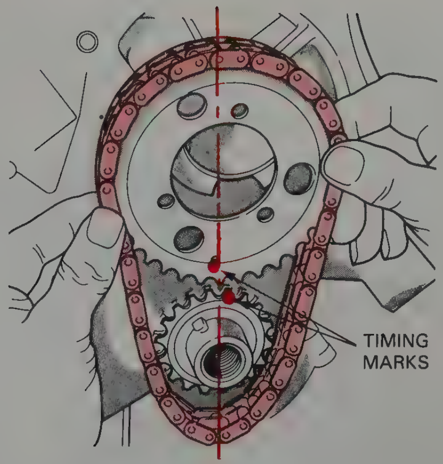


Fig. 15-18. Installing chain and camshaft sprocket. Timing marks are together and aligned with shaft centers. (Chrysler)

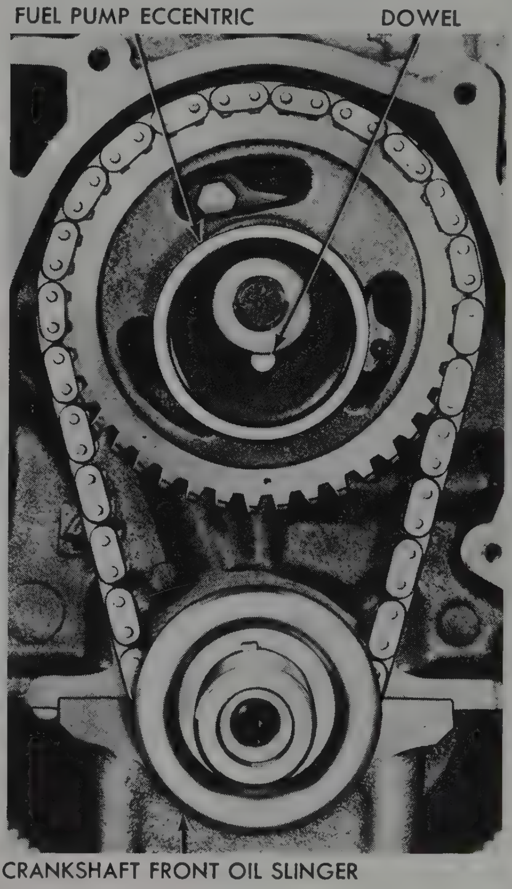


Fig. 15-19. Chain and sprockets installed. Fuel pump eccentric and front oil slinger are in place. (Ford)

REMOVE AND REPLACE CHAIN OR GEAR COVER OIL SEAL

Either drive out, or pull, the crankshaft front oil seal. When driving, support the cover so it is not sprung or cracked.

Fig. 15-20 illustrates the use of a special seal puller. In Fig. 15-20, A, the puller blocks have been expanded outward to grasp the retainer lip.

A removal sleeve is in place, Fig. 15-20, B. The puller screw is held stationary and the draw nut tightened. This will pull the seal.

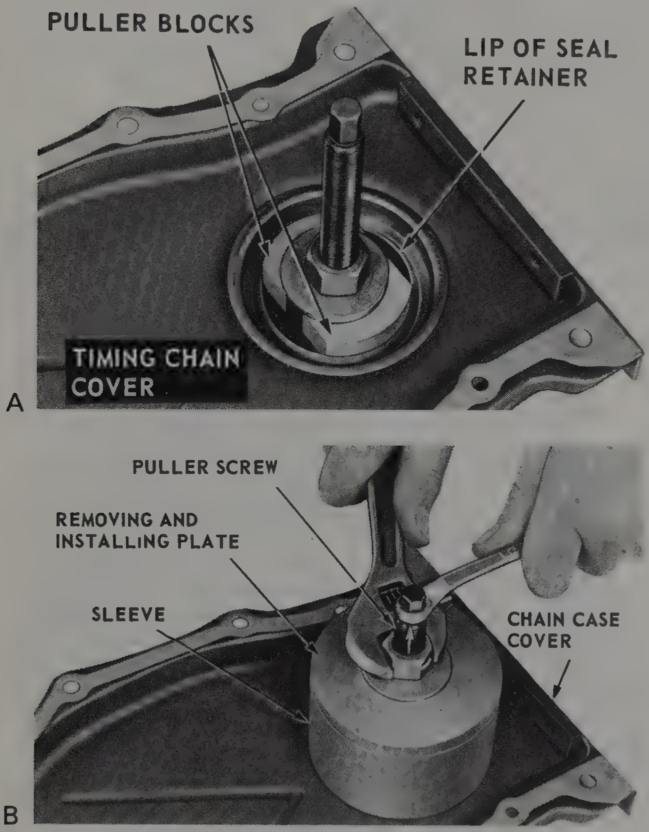

PULLER BLOCKS
LIP OF SEAL RETAINER
TIMING CHAIN COVER
A
PULLER SCREW
REMOVING AND INSTALLING PLATE
SLEEVE
CHAIN CASE COVER
B

Fig. 15-20. A—Puller blocks expanded to grasp seal retainer lip. (Chrysler) B—Pulling chain cover oil seal.

Clean the cover thoroughly. Coat the OD of the new seal with sealer and start into the seal recess. Install puller and plate, Fig. 15-21, A.

While holding the puller screw stationary, turn the draw nut to force the seal into place, Fig. 15-21, B.

Remove installing tool and check seal to make sure it is fully seated. On the particular seal shown in Figs. 15-20 and 15-21, a .001 in. (0.025 mm) feeler gauge should not fit between the cover and seal edge, when properly seated. Look at Fig. 15-22.

ALWAYS INSTALL THE SEALS SO THE SEAL LIP FACES TOWARDS THE ENGINE.

CHAIN OR GEAR COVER INSTALLATION

Cement the gasket into position. If dowel pins are used to properly locate the cover, it may be bolted into place. See Fig. 15-23.

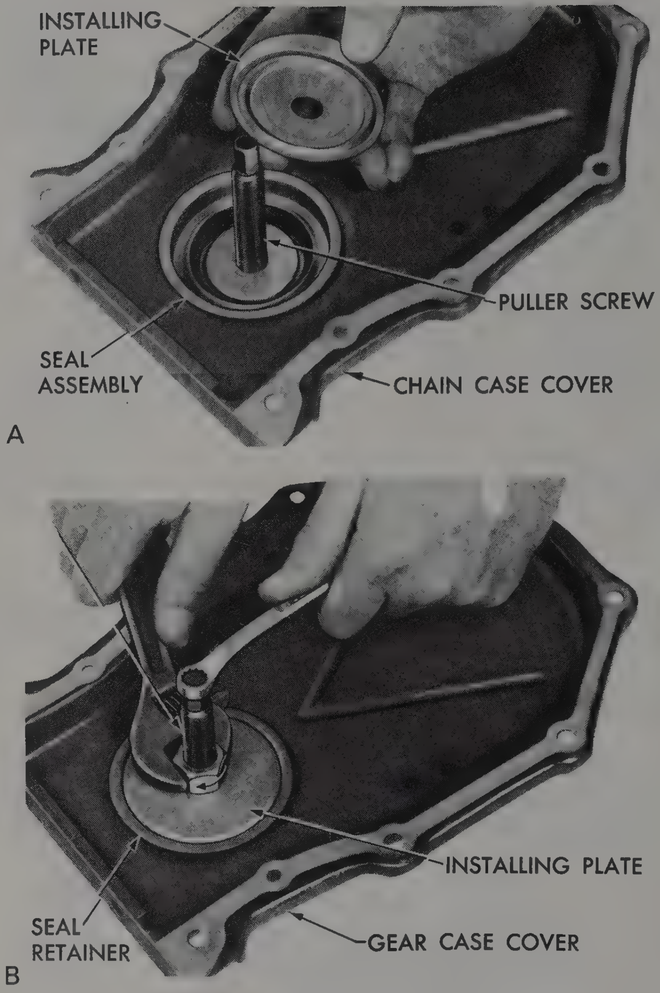

INSTALLING PLATE
PULLER SCREW
SEAL ASSEMBLY
CHAIN CASE COVER
A
INSTALLING PLATE
SEAL RETAINER
GEAR CASE COVER
B

Fig. 15-21. A—Setting up puller for seal installation. B—Pulling seal into place.

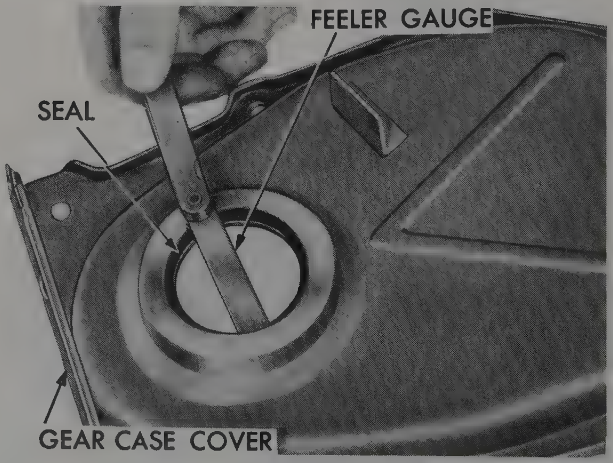

FEELER GAUGE
SEAL
GEAR CASE COVER

Fig. 15-22. Checking oil seal for proper seating depth. (Chrysler)

COVER CENTERING SLEEVE MAY BE NEEDED

If the cover is not positioned with dowel pins, it is IMPERATIVE THAT A SUITABLE CENTERING

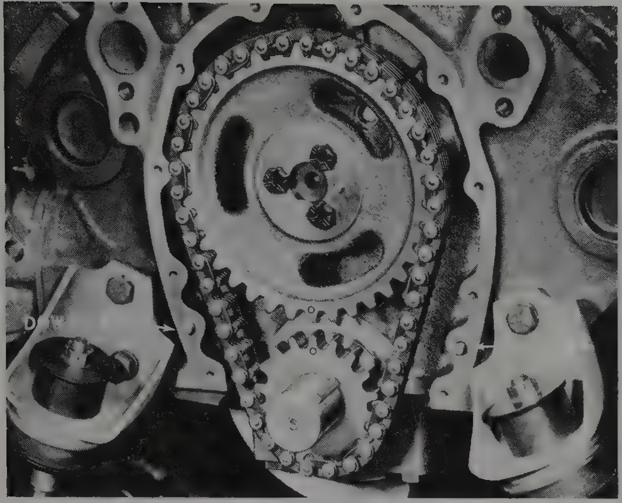


Fig. 15-23. Dowel pins will align cover so oil seal is properly centered around crankshaft. (Chevrolet)

SLEEVE BE USED.

The centering sleeve will line up the cover crankshaft seal with the crankshaft. If the sleeve is not used, the seal may be off center, causing it to leak.

Slide the sleeve over the crankshaft. Lubricate the sleeve. Slide the seal over the sleeve and force the cover against the block. Start all screws with finger pressure. With the sleeve in place, tighten screws properly. The sleeve is then withdrawn, leaving the seal centered perfectly around the crankshaft, Fig. 15-24.

VIBRATION DAMPER INSTALLATION

Lubricate the seal surface of the damper. MAKE SURE IT IS ABSOLUTELY SMOOTH TO PREVENT SEAL FAILURE. Install the damper (do not forget the Woodruff key) with a puller or by driving it into place. Seat fully, Fig. 15-25.

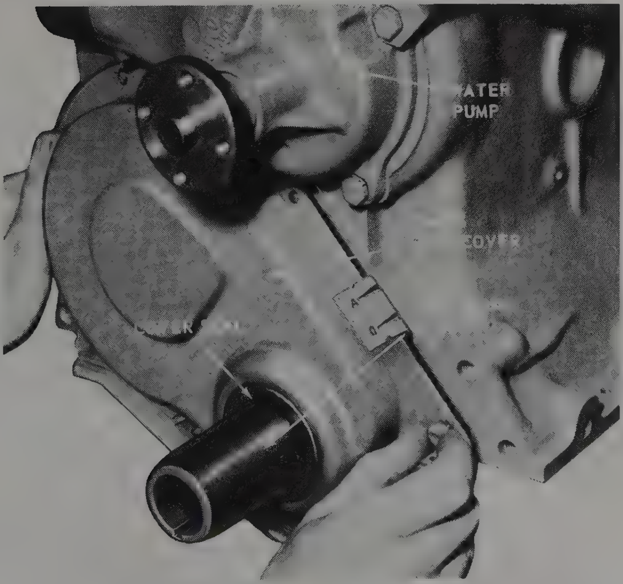

WATER PUMP
COVER

Fig. 15-24. Using centering sleeve to center oil seal with crankshaft. Tighten cover screws with sleeve in place. (G.M.C.)

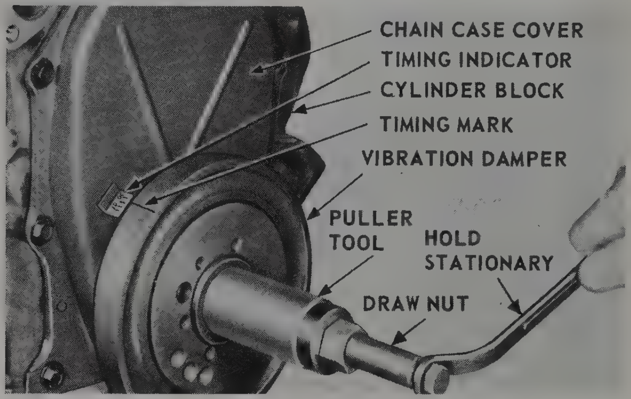

CHAIN CASE COVER
TIMING INDICATOR
CYLINDER BLOCK
TIMING MARK
VIBRATION DAMPER
PULLER TOOL
HOLD STATIONARY
DRAW NUT

Fig. 15-25. Seating vibration damper with puller. (Plymouth)

DO NOT DAMAGE DAMPER WHEN DRIVING ON

Some dampers can be damaged by driving unless a special driver, that supports the outer rim section, is used, Fig. 15-26.

Install pulley and if used, crankshaft end cap screw.

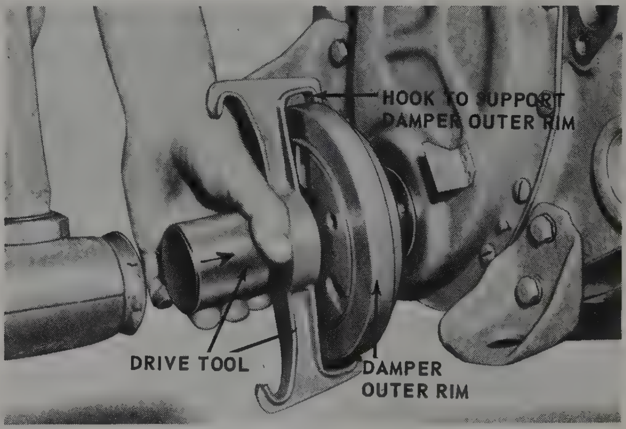

HOOK TO SUPPORT DAMPER OUTER RIM
DRIVE TOOL
DAMPER OUTER RIM

Fig. 15-26. This driver is designed to support damper outer rim thus protecting damper during installation. (G.M.C.)

CHAIN AND GEAR LUBRICATION

Always check timing chain or gear oil nozzles to make certain they are open. If feeder troughs are used, they must be clean and properly located. Improper lubrication will cause both gears and chain to quickly fail. When a timing cover is removed and the chain or gears are badly worn and dry looking, check out the lubrication system thoroughly.

Note the timing gear oil nozzle in Fig. 15-27.

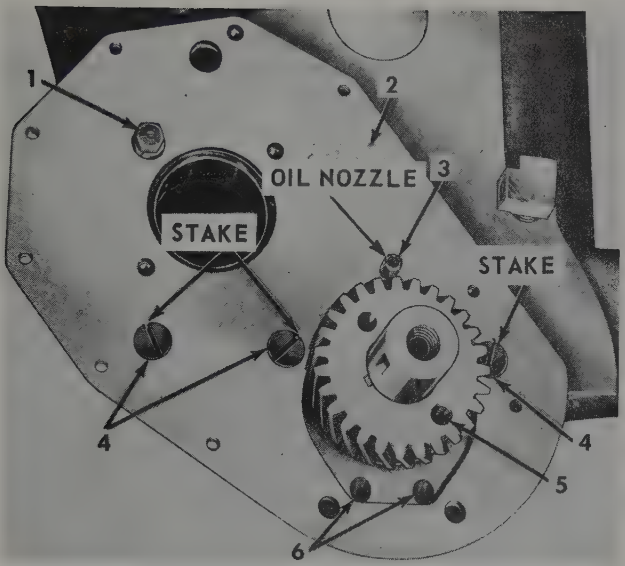


Fig. 15-27. Oil nozzle must be open. Front plate flat head screws are kept from loosening by staking — using punch to force portion of plate metal into edge of screw slots. Note oil drain to pan. 1—Plate bolt. 2—Front plate. 3—Oil nozzle. 4—Plate screws. 5—Crankshaft gear. 6—Pan oil holes.

OTHER TIMING CHAIN MARKS

Some manufacturers specify a certain number of links or pins between timing marks. Some chains have colored links that must be aligned with the timing marks, Fig. 15-28.

HANDLE GEAR AND SPROCKETS WITH CARE

Both gears and sprockets can be damaged by careless handling. Never hammer on them except with a proper driver and then only on the center hub. Avoid nicking or scratching the teeth. Keep clean and lubricate thoroughly upon assembly.

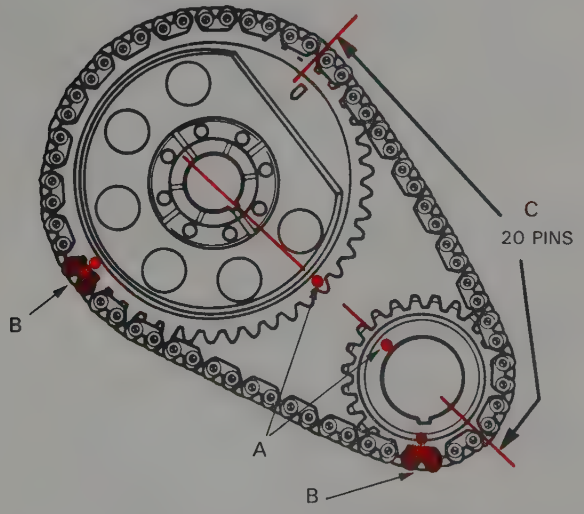


Fig. 15-28. Three methods of timing camshaft. A—Marks together and aligned with shaft centers. B—Colored links aligned with sprocket marks. C—Specific number of pins or links between marks. (Jeep)

TIMING BELT AND SPROCKET SERVICE

Some engines are being equipped with a ribbed fiberglass reinforced rubber timing belt to drive the camshaft, fuel pump, oil pump, and accessory shaft. The belt itself is generally driven with aluminum or sintered iron (metal formed by heating and compressing powdered iron and graphite into a solid) sprockets. See Fig. 15-29.

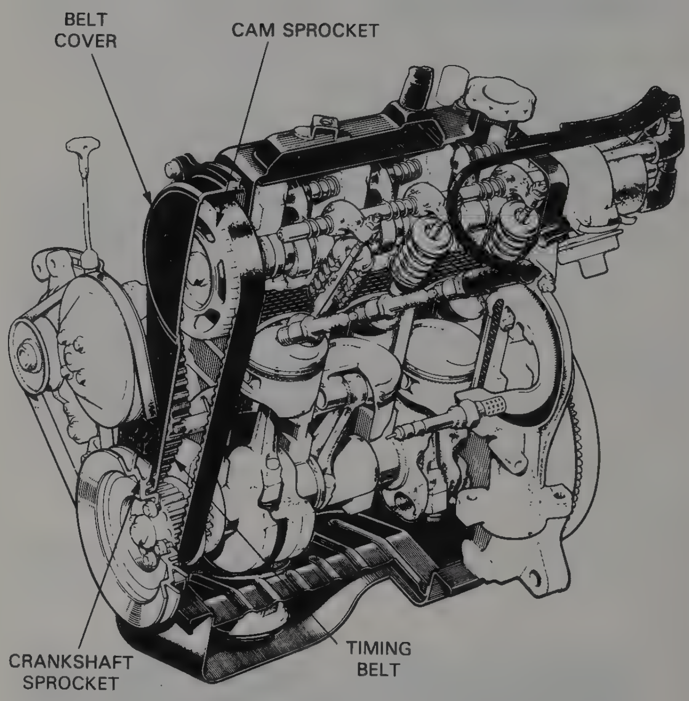


Fig. 15-29. This 1.5-liter engine uses a rubber, ribbed timing belt. Note that this is a three-cylinder engine. (Chevrolet)

TIMING BELT REMOVAL

The following is a basic procedure for timing belt removal. Follow manufacturer's recommendations for the engine at hand.

1. Remove water pump, air pump, and other belts.
2. Remove pulley(s).
3. Remove timing belt cover.
4. Line up timing marks.
5. Loosen belt tensioner.
6. Remove belt.

BELT INSPECTION AND PRECAUTIONS

If the timing belt is to be reused, examine it thoroughly for damage. CAUTION! When examining the belt, do not twist or bend it into a curved diameter of 1 in. (25 mm) or less. Also, do not turn it inside out. Carelessly handling the timing belt can cause core damage. Keep the belt away from oil, chemicals, direct sunlight, and excessive heat.

Check the belt for the following problems:

1. Hardened surface rubber.
2. Cracked back rubber.
3. Cracked or peeling canvas.
4. Badly worn teeth.
5. Cracked tooth bottom.
6. Missing teeth.
7. Worn or cracked belt sides.
8. Oil or water saturation.

If one or more of the listed conditions are present, replace the belt with a new one of the same quality. Some belt conditions are pictured in Fig. 15-30.

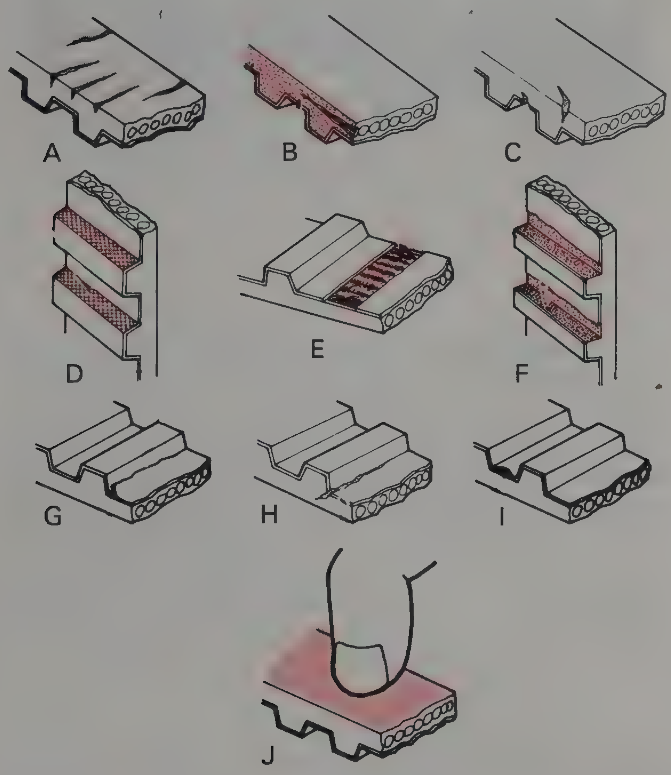


Fig. 15-30. Some common timing belt problems. If any are present, discard belt. A—Cracked belt back surface rubber. B—Side wear. C—Edge cracking. D—Flank on teeth worn (load side). E—Missing tooth, reinforcing belts exposed. F—Extreme flank wear. Canvas worn, rubber exposed. G—Cracked and separating canvas. H—Cracked canvas. I—Canvas separating from rubber. J—Back surface rubber hardened. Even firm pressure with fingernail will not leave marks. (Chrysler)

SPROCKET INSPECTION

After the belt has been examined, check all sprockets for looseness, tooth wear, burrs, or cracks. If any damage is found, replace the sprocket.

SPROCKET REMOVAL

Sprockets are generally pressed and/or bolted onto the camshaft, crankshaft, and accessory shaft. When removal is necessary, follow manufacturer's recommendations. Fig. 15-31 shows a particular crankshaft sprocket being removed with a special puller.

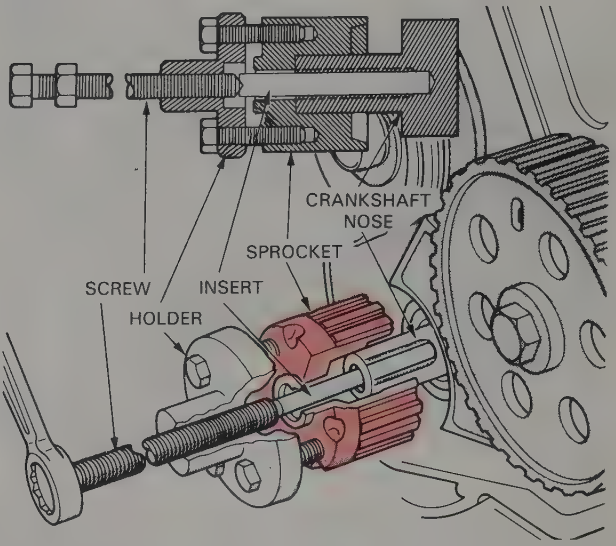


Fig. 15-31. The crankshaft sprocket is removed from the crankshaft nose using a special puller. (Chrysler)

SPROCKET INSTALLATION

When installing sprockets, make sure they are not turned around (front to back). Keys must be installed (where used) and the necessary timing marks lined up. Replace sprocket fasteners and torque to the recommended specification.

BELT INSTALLATION

The following is a basic belt installation procedure. Line up all sprocket timing marks and install belt, Fig. 15-32. Be sure belt is routed correctly.

Remove all spark plugs and revolve the crankshaft to TDC (top dead center) in the direction of normal travel. Turning the crankshaft backwards can cause the belt to skip teeth and alter the timing. Place the belt tensioner tool horizontally on the tensioner hex and loosen the tensioner locknut. Rotate the crankshaft through two full revolutions from TDC. Secure the locknut on the tensioner while keeping the belt tensioning tool in position. See Fig. 15-33.

CAUTION! After you start the engine, if a whirring sound is heard, stop the engine. This sound indicates that the belt is too tight. This condition will greatly reduce the belt's service life.

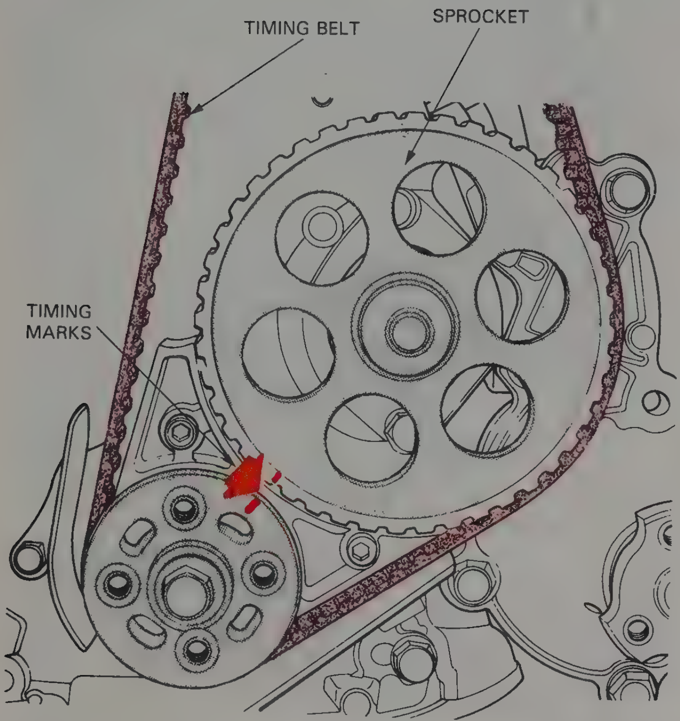


Fig. 15-32. Sprockets and belt installed. Timing marks are lined up correctly. If other driven unit sprockets must be timed also, align their marks as per manufacturer's specifications. (Chrysler)

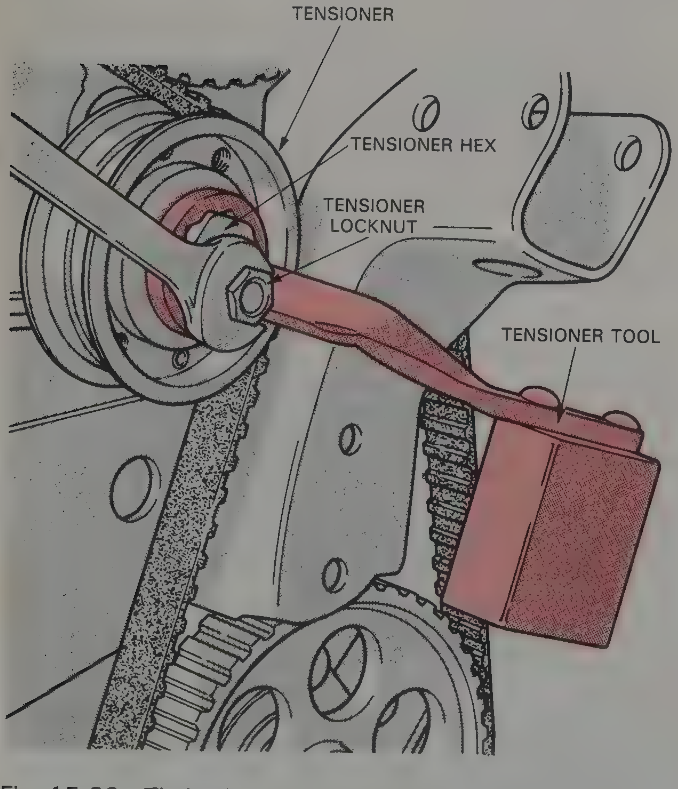


Fig. 15-33. Timing belt tension is being adjusted. Note how tool is placed on large hex on face of tensioner. (Chrysler)

CHECKING CAMSHAFT JOURNAL-TO-BEARING CLEARANCE

Camshaft journal-to-bearing clearance can be checked in several ways. Feeler (narrow blade) gauges of varying thickness can be inserted between the camshaft journal and bearing until the clearance is determined. Do not force the gauge and damage the bearing surface. Maximum clearance will be around .005-.006 in. (0.13-0.15 mm). See Fig. 15-34.

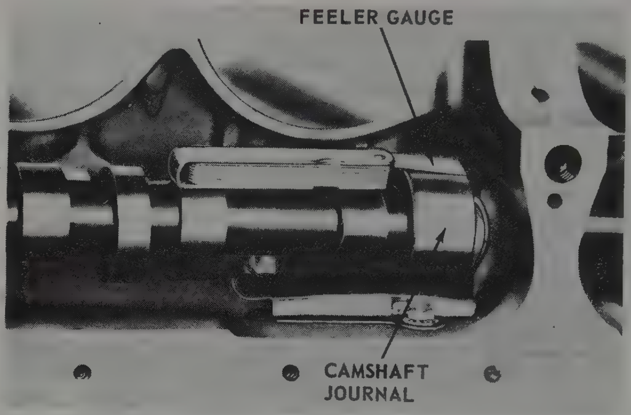


Fig. 15-34. Checking camshaft journal bearing clearance with feeler gauge. (G.M.C.)

A dial indicator can be set up so that when the camshaft is forced up and down (right angles to bore) the movement (clearance) will be indicated.

A small hole gauge (camshaft removed) can be used to measure the bearing ID (inside diameter). By subtracting the diameter of the journal from the bearing ID, an accurate indication of clearance will be given. Check the bearings for signs of wiping, imbedded dirt, and scoring.

CAMSHAFT INSPECTION

Clean, rinse, blow dry, and lightly oil the camshaft. Mike each journal in several spots to determine the amount of wear and the extent of out-of-roundness. Overall wear exceeding .0015 in. per inch (0.038 mm per 25.4 mm) of journal diameter or out-of-roundness beyond .001 in. (0.025 mm) will require regrinding and the use of undersize inserts. Journals must be smooth.

Check camshaft journal alignment with V-blocks and a dial indicator. Check specs for maximum runout (varies from .002 to .005 in. or 0.05 to 0.13 mm depending on design). Refer to Fig. 15-35.

Inspect each cam lobe for signs of galling, chipping, or excessive wear. The wear pattern will usually vary in width, being somewhat narrower on the base circle and widening toward the nose of the cam. The pattern may be somewhat off-center, Fig. 15-36.

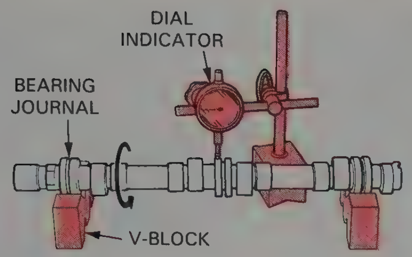

DIAL INDICATOR
BEARING JOURNAL
V-BLOCK

Fig. 15-35. Testing camshaft journal runout with dial indicator. Note how V-blocks hold camshaft. (Mazda)

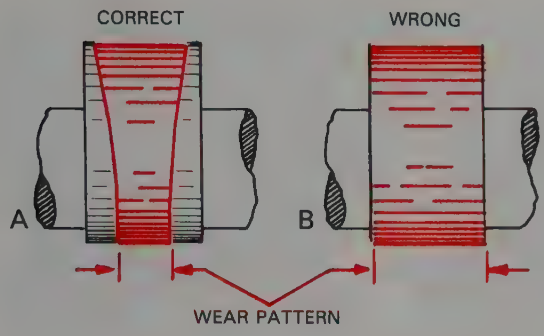

CORRECT
WRONG
A
B
WEAR PATTERN

Fig. 15-36. Usual cam lobe wear pattern. A—Correct. B—Wrong.

The wear pattern should not show across the full width of the lobe. The majority of camshafts are ground so the cam lobe surface is slightly tapered. By grinding the bottom of the lifter with a slight crown and placing it a trifle off-center, in relation to the cam, the lifters will tend to rotate. Also, the loading (pressure) area will not extend to the edge of the lobe where it could cause damage, Fig. 15-37.

When lifter bottoms are reground, the original crown should be retained. If they are ground flat, edge loading will result and both cam and lifter wear will be greatly accelerated, Fig. 15-38.

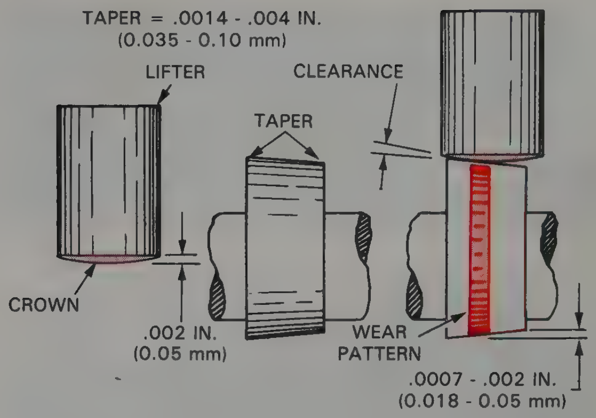

TAPER = .0014 - .004 IN.
(0.035 - 0.10 mm)
LIFTER
CLEARANCE
TAPER
CROWN
.002 IN.
(0.05 mm)
WEAR PATTERN
.0007 - .002 IN.
(0.018 - 0.05 mm)

Fig. 15-37. Cams are often ground with a taper. Lifter base is crowned.

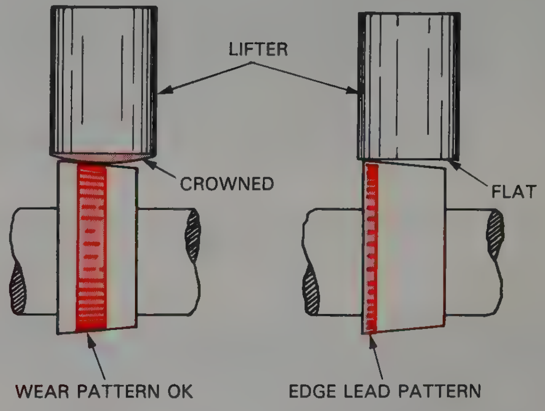
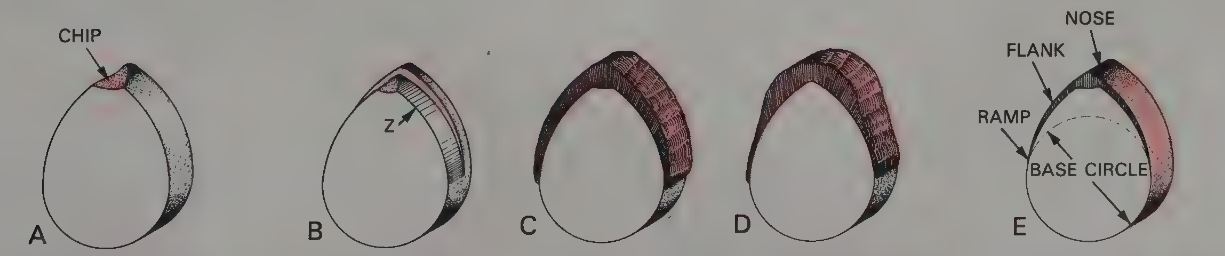

LIFTER
CROWNED
FLAT
WEAR PATTERN OK
EDGE LEAD PATTERN

Fig. 15-38. If lifter base is reground, crown should be retained. Flat base will cause damage from edge loading.

WELDING AND REGRINDING

A chipped or badly worn cam can be built up by welding, then reground to original specifications. Camshaft replacement cost will determine the advisability of this procedure. Study Fig. 15-39.


CHIP
A
Z
B
C
D
NOSE
FLANK
RAMP
BASE CIRCLE
E

CAM WITH CHIPPED CORNER BEFORE ECCENTRIC GRINDING AS SHOWN IN ILLUSTRATION B. ECCENTRIC GRINDING REMOVES OIL SOAKED SURFACE WHICH MIGHT PREVENT ADHESION OF WELDING MATERIAL.

Z IS SURFACE PRODUCED BY GRINDING OFF FLANK AND NOSE ONLY IN PREPARATION FOR SURFACE WELDING.

SHOWS FLANK AND NOSE OF CAM BUILT UP BY SURFACE WELDING.

SHOWS MATERIAL APPLIED TO PERMIT CHANGING OF CAM CONTOUR.

REGROUND CAM SHOWN WITH HARD SURFACE WELD COVERING FLANK AND NOSE. THICKNESS OF COATING APPROX. .020 IN. (0.51 mm).

Fig. 15-39. Chipped cam lobe repaired by welding and grinding. (Van Norman)

A camshaft showing reasonable wear on either journals or cams, can often be repaired by grinding. Undersize inserts are then required.

The shaft is straightened and then ground. As with crankshaft grinding, the cam grinding equipment must be highly accurate and the operator fully experienced, Fig. 15-40.

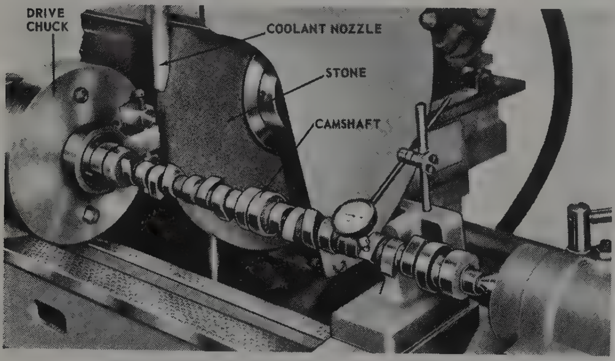

DRIVE CHUCK
COOLANT NOZZLE
STONE
CAMSHAFT

Fig. 15-40. Regrinding a camshaft.

Camshafts are generally surface hardened to a depth of at least .040 in. (1.01 mm). When regrinding, the journals are customarily ground either .010 or .020 in. (0.25 or 0.51 mm) undersize. The new inserts are then align bored to produce the proper bearing clearance of from .001 to .003 in. (0.025 to 0.08 mm). To provide proper break in and longer wear, many regrinders cover the cam lobes (never the journals) with a special phosphate coating.

INSTALLING NEW CAMSHAFT BEARINGS

Some engines use two-piece camshaft bearings. The camshaft bearing caps are removed to allow access to the camshaft. See Fig. 15-41.

With one-piece bearings, the old inserts are either driven or pulled out. The bore may be slightly chamfered on the front side so that material will not be shaved from the new bearing as it is forced into place. Look at Fig. 15-42.

Clean the bore and oil delivery holes. Bores should then be checked for size and alignment.

There are a number of camshaft bearing removing and installing tools. The proper size mandrel is selected and fitted to the drive bar, Fig. 15-43.

The bar is passed through the bores until the mandrel is positioned. The insert is oiled and slipped on the mandrel. Rotate the bar until the mandrel expands snugly inside the insert. Align the oil hole in the bearing with the one in the bore and start the bearing by hand, Fig. 15-44.

At this point, rotate the bar one-eighth turn counterclockwise. This will reduce the mandrel diameter about .004 in. (0.10 mm) to allow the bearing ID to reduce as it is driven into place, Fig. 15-45.

Using a hammer, drive the bearing into the bore, Fig.

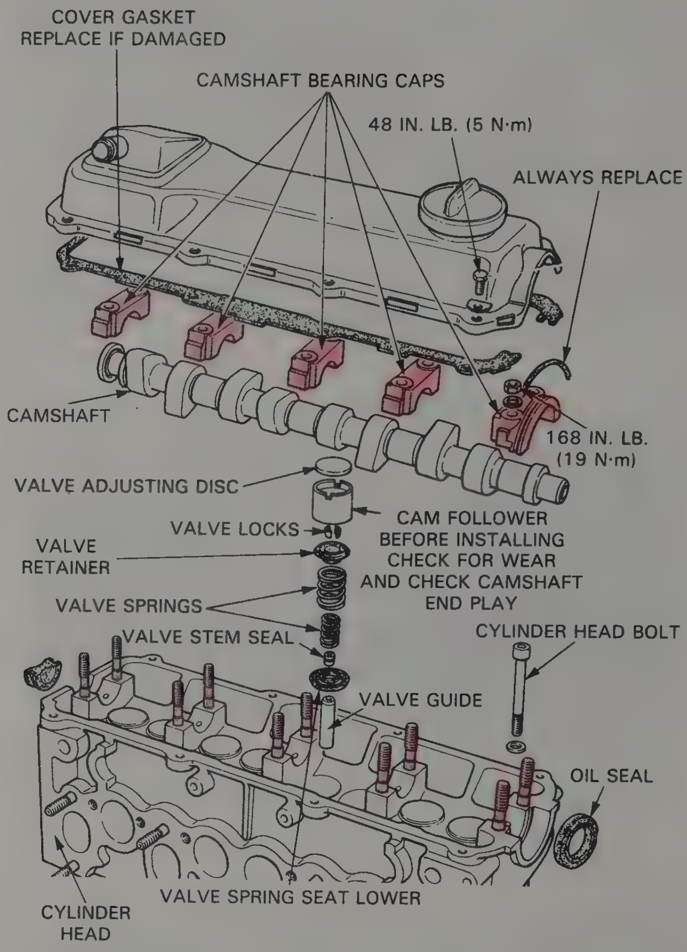

COVER GASKET
REPLACE IF DAMAGED
CAMSHAFT BEARING CAPS
48 IN. LB. (5 N·m)
ALWAYS REPLACE
CAMSHAFT
168 IN. LB.
(19 N·m)
VALVE ADJUSTING DISC
VALVE LOCKS
CAM FOLLOWER
BEFORE INSTALLING
CHECK FOR WEAR
AND CHECK CAMSHAFT
END PLAY
VALVE
RETAINER
VALVE SPRINGS
VALVE STEM SEAL
CYLINDER HEAD BOLT
VALVE GUIDE
OIL SEAL
VALVE SPRING SEAT LOWER
CYLINDER
HEAD

Fig. 15-41. One type of four cylinder engine using two-piece camshaft bearings. Cylinder head houses integral bottom half of bearings. Removable bearing caps make up top half. (Chrysler)

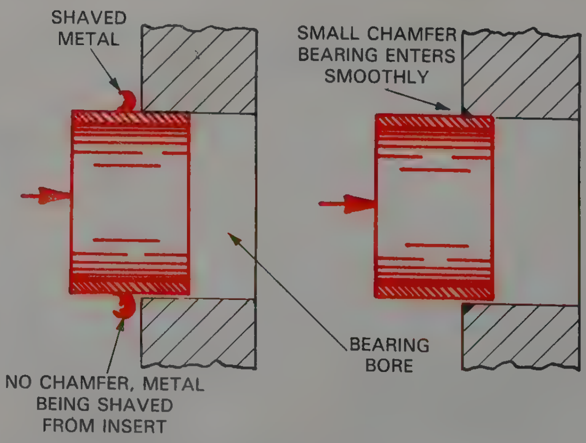

SHAVED
METAL
SMALL CHAMFER
BEARING ENTERS
SMOOTHLY
BEARING
BORE
NO CHAMFER, METAL
BEING SHAVED
FROM INSERT

Fig. 15-42. Chamfer bearing bore on front side. A SMALL chamfer is ample.

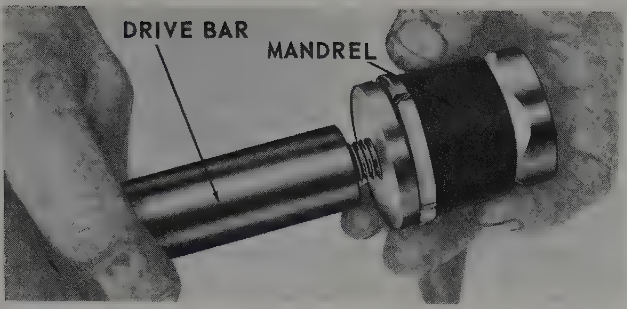


Fig. 15-43. Fitting proper mandrel to drive bar. (Dura-Bond)

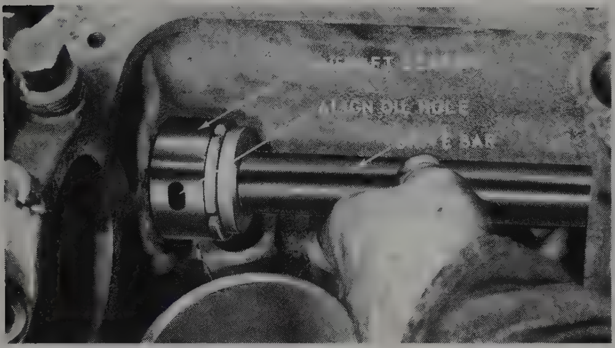


Fig. 15-44. Bearing on mandrel, oiled, oil holes aligned, and started into bore by hand.

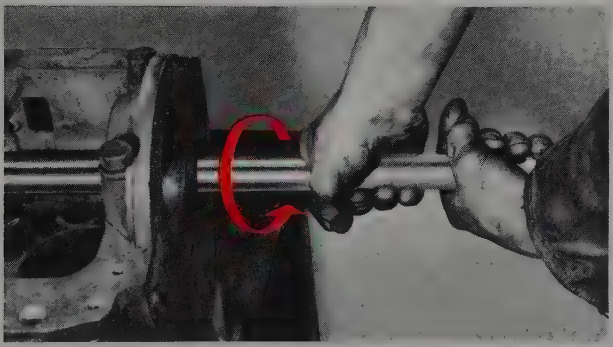


Fig. 15-45. Rotate drive bar 1/8 turn counterclockwise. This will loosen mandrel in camshaft bearing to allow bearing ID to decrease when bearing is driven into place.

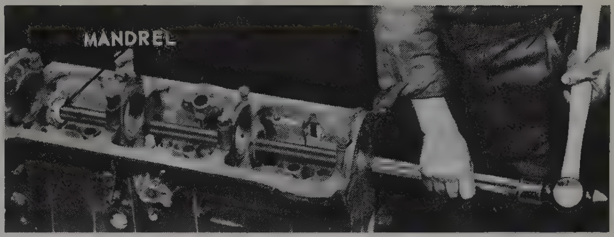


Fig. 15-46. Driving camshaft bearing into place.

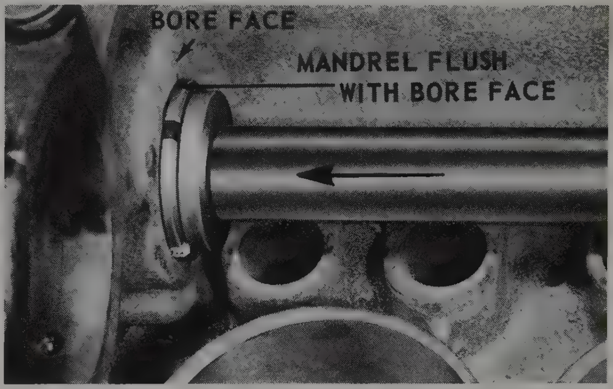


Fig. 15-47. Drive bearing in until mandrel is flush with bearing bore face. (Dura-Bond)

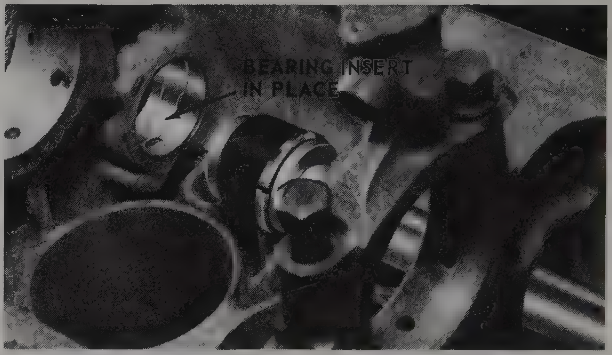


Fig. 15-48. Drive bar and mandrel being removed. Camshaft bearing fully seated. Check oil hole alignment.

15-46. Stop driving when the drive face of the mandrel is flush with the bore, Fig. 15-47.

Remove the bar. CHECK TO MAKE CERTAIN THE OIL HOLE IS CORRECTLY ALIGNED, Fig. 15-48.

When installing cam bearings, be sure they are started STRAIGHT. The oil holes must be ALIGNED, and material must not shave as the bearing enters. If the bearing is cocked, it will be distorted. It can even become loose enough to rotate and cut off the oil supply.

If the front bearing is specially designed to provide lubrication for the timing chain or gears, get the right end forward. Install it to the proper depth.

If the bearing shells are chamfered on one end, start them so the chamfer enters the bore first. When possible, install the split seam toward the top of the engine (away from the high load area). If the original inserts were staked in place (a portion of shell dented into a recess with a punch) the new inserts should also be staked to prevent the insert from turning.

Following align boring, if needed, clean and lubricate the bearings. Oil and CAREFULLY INSTALL CAMSHAFT. The edges of the cam lobes and gear teeth can damage the soft babbitt bearing lining very easily. Use extreme care, Fig. 15-49.

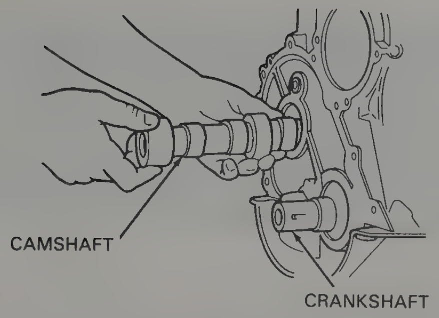

CAMSHAFT
CRANKSHAFT

Fig. 15-49. When installing a camshaft, be careful not to damage the bearing surfaces. (Jeep)

CAMSHAFT REAR BEARING CORE PLUG OR OIL SEAL PLUG

When replacing the camshaft rear bearing oil seal plug (often called Welch plug or core hole plug), clean out the plug counterbore. Coat both the OD of the new plug and the counterbore sides with sealer. Drive the plug in SQUARELY. Unless a stop ledge is provided, do not drive below recommended depth. Use a suitable driver that contacts the plug OUTER EDGE.

Some plugs require (after full seating with driver) striking in the center to expand the plug tightly. This type of plug is crowned. Install with the crown facing outward, Fig. 15-50.

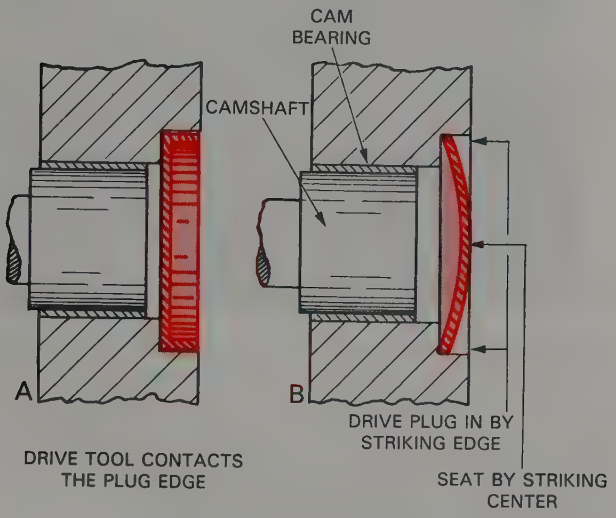

CAM BEARING
CAMSHAFT
A
B
DRIVE TOOL CONTACTS THE PLUG EDGE
DRIVE PLUG IN BY STRIKING EDGE
SEAT BY STRIKING CENTER

Fig. 15-50. Typical camshaft rear journal oil seal plugs. A—Driven in on edge. B—Driven in on edge and seated with blow in center.

As with all plug installations, use care to effect a strong, permanent seal. If a leak develops after engine installation, the repair can be VERY EXPENSIVE and to the mechanic responsible for the job, MOST EMBARRASSING.

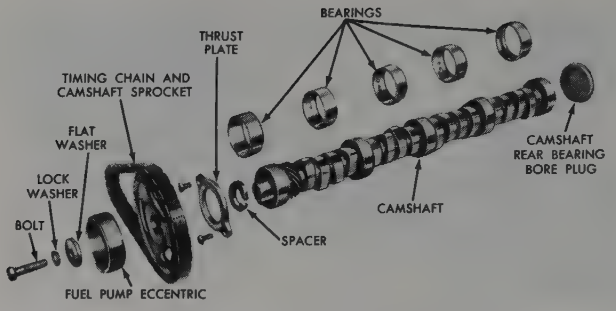

BEARINGS
THRUST PLATE
TIMING CHAIN AND CAMSHAFT SPROCKET
FLAT WASHER
LOCK WASHER
BOLT
CAMSHAFT REAR BEARING BORE PLUG
CAMSHAFT
SPACER
FUEL PUMP ECCENTRIC

Fig. 15-51. Typical chain driven camshaft for V-8 engine. (Ford)

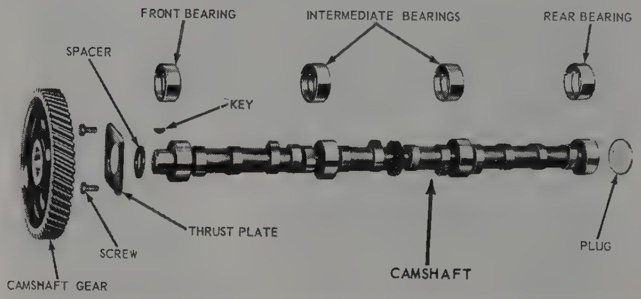

FRONT BEARING
INTERMEDIATE BEARINGS
REAR BEARING
SPACER
KEY
THRUST PLATE
SCREW
PLUG
CAMSHAFT
CAMSHAFT GEAR

Fig. 15-52. Gear driven camshaft for a straight six engine.

Fig. 15-51 illustrates a complete camshaft, bearing, and chain layout for a V-8 engine. Note the bolt-on fuel pump eccentric.

Fig. 15-52 shows a typical 6-cylinder gear driven camshaft. Note the integral fuel pump eccentric.

Fig. 15-53 illustrated one particular belt driven camshaft arrangement for a six-cylinder engine.

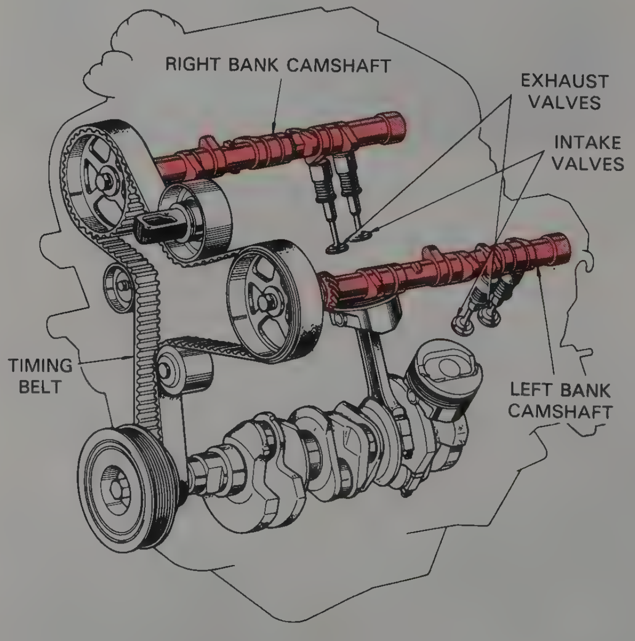

RIGHT BANK CAMSHAFT
EXHAUST VALVES
INTAKE VALVES
TIMING BELT
LEFT BANK CAMSHAFT

Fig. 15-53. One type of dual overhead camshaft arrangement. Note the toothed drive belt. (Toyota)

CAMSHAFT DRIVE THRUST DIRECTION

Some camshafts, during operation, tend to move toward the rear of the engine. This type does not utilize a bolt-on thrust flange. Those that exert a forward thrust must obviously be restrained.

CHECKING CAM LOBE LIFT

When the cam lobes wear, they may not raise the lifters to the specified height. This in turn reduces the valve opening or lift distance. Refer to Fig. 15-54.

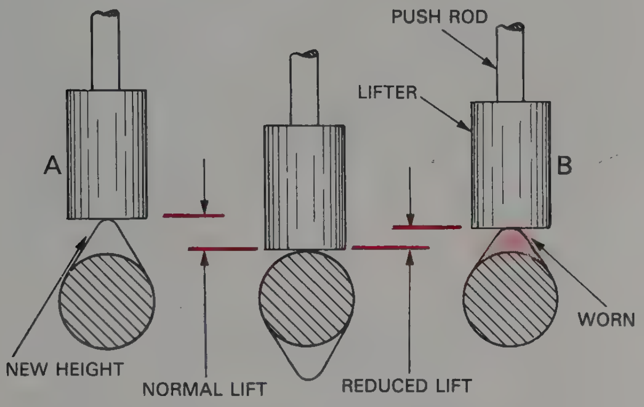


Fig. 15-54. Cam wear lowers lift. A—No wear on cam, normal lift. B—Worn cam, reduced lift.

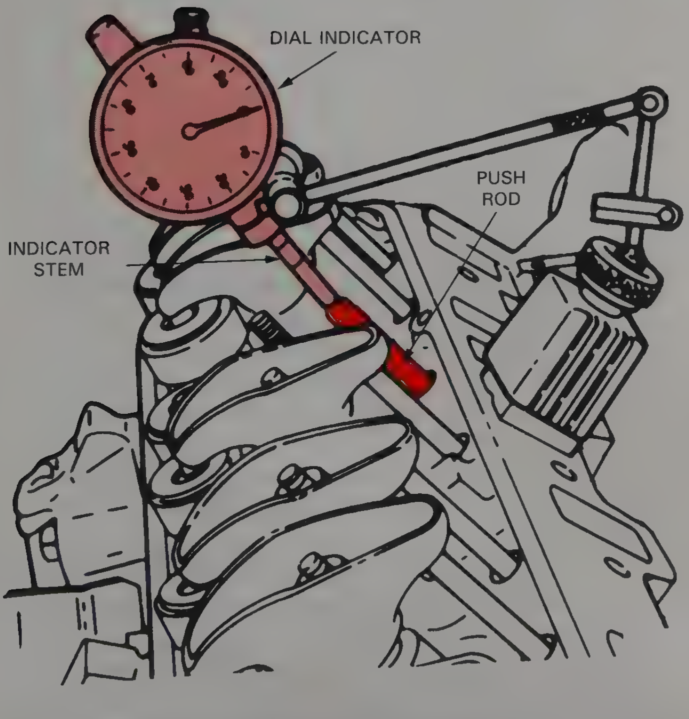


Fig. 15-55. Camshaft lobe lift is checked using a dial indicator. Keep the indicator stem parallel to the push rod. (Chevrolet)

With the cam out of the engine, cam lobe lift can be checked with V-blocks and a dial indicator. If the cam is in the engine, lift can be checked by mounting a dial indicator as shown in Fig. 15-55.

The push rod is held down. The crankshaft is turned until the lifter is riding on the cam base circle (lowest indicator reading). At this point, zero the indicator and crank the engine slowly until the lifter rests on the cam nose. Do this SLOWLY so you may record the HIGHEST READING on the indicator as the nose passes under the lifter. The TIR (total indicator reading) will be the amount of lift. Check specs for maximum lobe lift wear.

SUMMARY

Camshafts, camshaft bearings, timing gears, chains, belts, and sprocket conditions are of critical importance to proper engine performance.

Pull and install the vibration damper by exerting pressure on the hub portion. Do not damage the crankshaft end thread.

Timing gear teeth must be smooth. Gear runout and backlash must be within limits. Some camshaft timing gears are bolted on, others are pressed on.

When replacing a gear or a sprocket, it is good practice to replace the mating gear or sprocket.

When replacing a timing belt, check sprockets for possible damage. Remove and install the camshaft carefully to avoid damage to the bearing surfaces.

When pressing a new timing gear into place, apply pressure to the hub only.

Check camshaft end play at the thrust plate with a feeler gauge. A dial indicator can also be used.

Install the crankshaft gear before the camshaft gear. Make certain gear timing marks face outward and that they are aligned.

Never pound on gears, chains, belts, camshafts, or sprockets.

When replacing a timing chain, install new sprockets. Check sprocket runout and chain slack. The chain and sprockets must mesh to properly align the timing marks. Some timing instructions call for sprocket marks to face each other on a line between crank and camshaft centers. Some call for colored links to align with the marks. Others give a specific number of links or pins between marks.

Slack in long chains is often controlled with rubbing blocks and tensioning devices.

Place chain around sprockets and install as a unit.

Replace all Woodruff keys. Then, install gears, sprockets, or vibration damper.

Never force a camshaft back into the engine as it may loosen the rear bearing core hole plug.

Always install a new chain or gear cover oil seal - lip facing the engine. Center seal to crankshaft before tightening cover screws. Vibration damper seal contact area must be smooth.

Lubricate all gears, chains, and bearings before installation. Never lubricate a timing belt.

Camshaft bearing clearance must be checked. Replace bearings if necessary. Align oil holes when installing. Check camshaft bearing journals, distributor drive gear, fuel pump eccentric cam, and cam lift.

CHECKLIST FOR CAMSHAFT, GEAR, CHAIN, AND BELT SERVICE

The following important questions relating to camshaft, bearing, gear, belt, and chain service MUST BE ANSWERED WITH "YES."

1. Are timing gear teeth smooth and sound?
2. Is the timing gear backlash correct?
3. Is gear runout within limits?
4. Is camshaft end play as specified?
5. Are the timing marks properly aligned?
6. Are the chain (or belt) sprockets in good condition?
7. Is chain (or belt) slack within limits?
8. Is sprocket runout acceptable?
9. Are the chain (or belt) and sprockets meshed so the timing marks align properly?
10. If rubbing blocks or tensioners are used, are they in good condition and properly placed and adjusted?
11. Were all Woodruff keys replaced?
12. Is the chain or gear oiling nozzle clean?
13. Are camshaft journals smooth, round, and within maximum wear limits?
14. Is the camshaft runout within limits?
15. Are the cam lobes in good condition and is lift as specified?
16. Are the cam bearings good and do they provide correct clearance?
17. Are the cam bearings oil holes aligned?
18. Are the cam bearings secure in the bore and were they pressed in the proper distance?
19. Is the distributor-oil pump drive gear in good condition?
20. If a thrust plate is used, is wear within limits and is it securely bolted into place?
21. Have camshaft gears and sprocket cap screws been torqued?
22. If detachable, is the fuel pump eccentric and distributor drive gear secured in place?
23. Is the rear camshaft bearing oil seal plug sealed and tightly installed?
24. Is the crankshaft oil slinger correctly in place?
25. Was a new oil seal installed in the gear or chain cover—lip facing engine?
26. Was the chain cover oil seal properly centered in relation to the crankshaft before tightening the cover?
27. Is the damper on securely and to the proper depth?
28. Is the damper seal lip contact surface smooth and oiled?
29. If a damper retaining cap screw is used, is it in place and torqued?
30. Was the damper carefully installed so it was not damaged?
31. Were all gears, chains, journals, and cams thoroughly lubricated before assembly?
32. Are you proud of the job?

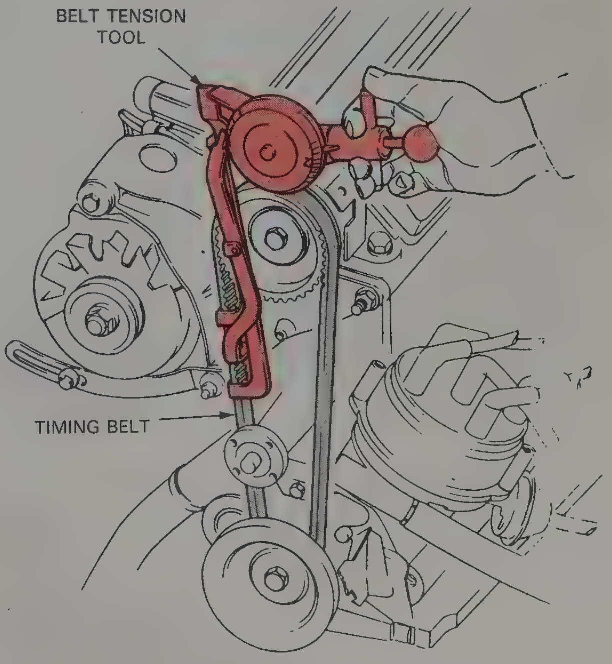
KNOW THESE TERMS

Valve timing, Gear backlash, Woodruff key, Cam thrust plate, Timing chain, Overhead camshaft, Core plug, Cam lobe lift, Timing belt, Timing gear, Ribbed belt, Vibration damper, Harmonic balancer, Timing chain cover, Gear runout, Rubbing block, Chain slack, Timing mark, Idler sprocket, Chain tensioner, Welch plug, Centering sleeve, Oil nozzle, Lobe crown, Undersize insert, Reground, Mandrel, Bore face, Staked insert, Bolt-on eccentric, TIR (total indicator reading), Camshaft sprocket, Camshaft end play, Belt slack, Camshaft runout.

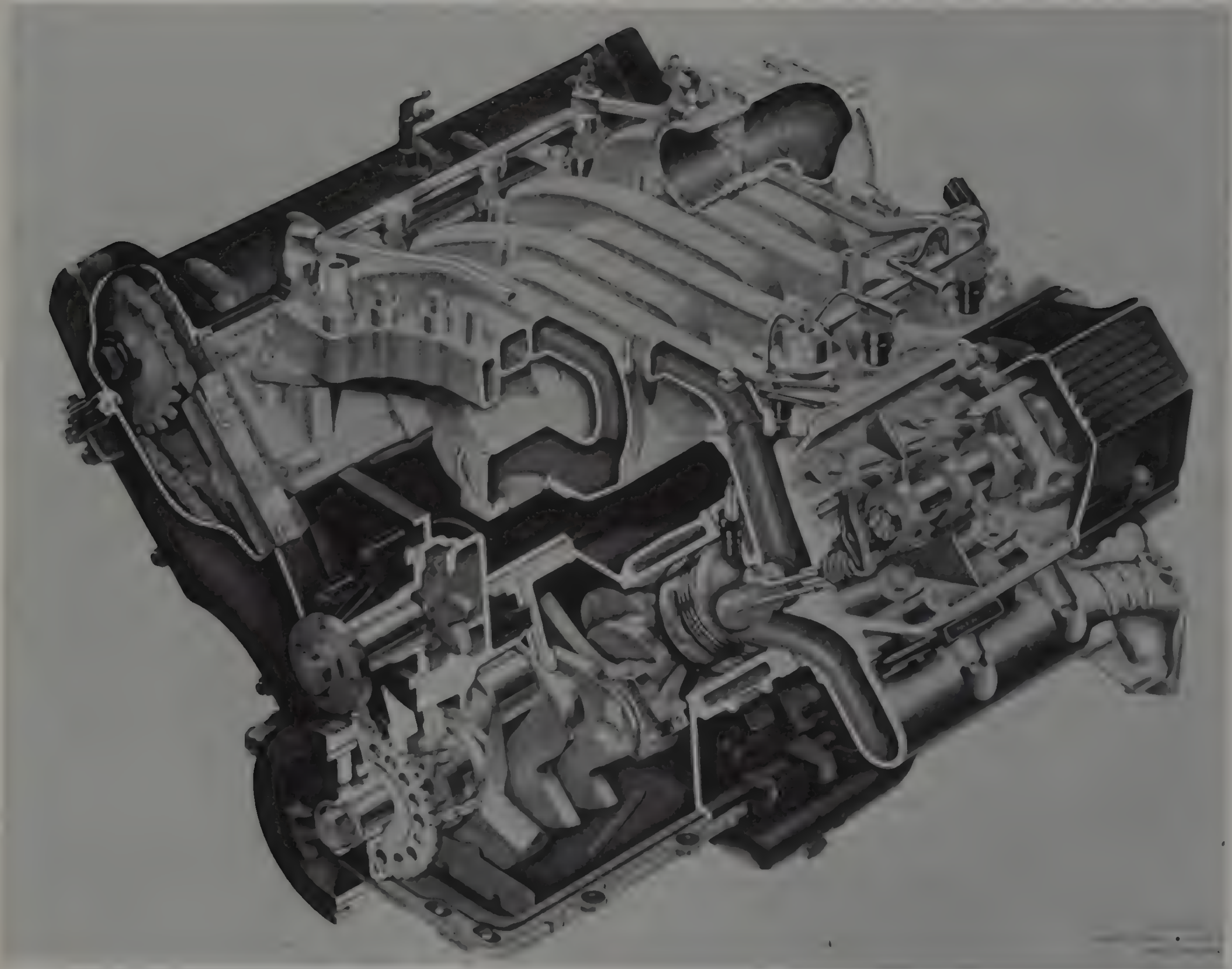
QUIZ - Chapter 15

1. Worn camshaft bearings can cause:
   a. Excessive shaft end play.
   [✓ b.] Excessive oil consumption.
   c. Crankshaft failure.
   d. Loose vibration damper.
2. Worn timing gears, sprockets, or chains will:
   [✓ a.] Alter valve timing.
   b. Cause crankcase fumes.
   c. Increase oil consumption.
   d. Reduce engine oil pressure.
3. Pull vibration dampers by grasping the outer rim. True or [✓ False?]
4. Gear backlash can be checked with a feeler gauge or a dial indicator.
5. Installing new gears will automatically provide correct backlash. True or [✓ False?]
6. When removing or installing a camshaft, be very careful to avoid damaging Cam bearings
7. When installing a bolt-on timing gear or sprocket, it is best to:
   a. Drive the gear tightly against the camshaft.
   [✓ b.] Start the gear and use the cap screws to pull it on.
   c. Tighten the cap screws a little, drive on a small amount, tighten cap screws again, drive on, until gear is seated.
8. Gear and sprocket runout is of little or no importance. True or [✓ False?]
9. An average acceptable gear backlash would be around 064 00.

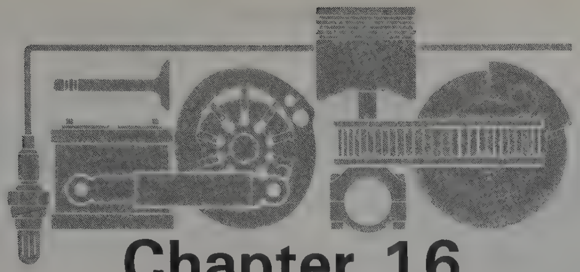
10. Timing chains with slack in excess of [illegible] (most engines) would require replacement.
11. All camshafts use a bolt-on thrust plate. True or [✓ False?]
12. When installing a gear driven camshaft, the timing marks should:
    a. Face in opposite directions.
    b. Be placed 90 deg. apart.
    [✓ c.] Face each other in perfect alignment.
    d. Both be in the down position.
13. Some pressed on camshaft timing gears can be replaced with the camshaft in the engine. [✓ True] or False?
14. Describe TWO methods of checking for excessive chain slack.
15. Slack in long timing chains is often controlled through the use of [illegible] [illegible] and a Spring loaded device.
16. When replacing a timing chain, it is good practice to also replace:
    a. The camshaft.
    b. The camshaft sprocket.
    [✓ c.] Both sprockets.
    d. The oil slinger.
17. Describe the three methods used to time the camshaft when a timing chain is used. [illegible]
18. Before installing the chain or gear cover, you should:
    [✓ a.] Replace the oil seal.
    b. Replace the oil seal if worn.
    c. Soak the old seal to make it pliable.
    d. Tighten the old seal to prevent leakage.
19. Before bolting on the timing gear cover, the Seal cover should be centered around the block by using a Centering sleeve
20. The cover oil seal lip should face the engine. [✓ True] or False?
21. To insure proper lubrication, make certain any oiling devices are Straigh and properly align.
22. Camshaft journal-to-bearing clearance can be determined by using a feeler gauge, a dial indicator, or by using a small hole gauge and a micrometer.
23. Most camshaft lobes are:
    [✓ a.] Ground on a slight taper.
    b. Ground with a slight crown.
    c. Ground flat.
    d. Ground slightly concave.
24. A camshaft wear pattern should cover the complete width of the lobe. True or [✓ False?]
25. Typical camshaft journal to bearing clearance would be about 005 - 006
26. Camshaft journal out-of-roundness should not exceed:
    a. .0001 in. (0.0025 mm).
    b. .1115 in. (2.832 mm).
    [✓ c.] .001 in. (0.025 mm).
    d. .010 in. (0.25 mm).
27. Camshaft journal runout is best checked with a dial indicator and V Blocks.
28. Overall journal wear should not exceed (per inch or 25.4 mm of shaft diameter):
    a. .100 in. (2.54 mm).
    [✓ b.] .0015 in. (0.0381 mm).
    c. .008 in. (0.20 mm).
    d. .0001 in. (0.0025 mm).
29. Camshafts can often be salvaged by welding. regrinding
30. Prior to installing new cam bearings, the leading edge of the bearing bore should be slightly Chamfered
31. Camshaft bearing oil passage must be accurately aligned with those in the bore.
32. When installing rear camshaft journal bore plugs, drive them in by striking in the center only. True or [✓ False?]
33. Worn cams will reduce valve lift and opening.
34. List eight types of damage to look for when inspecting a timing belt.
35. Timing belts can be used to drive accessory shafts and oil pumps while driving the camshaft. [✓ True] or False?
36. Timing belt sprockets are commonly produced from [illegible] or sintered iron.
    Fibber glass



Timing belt tension is checked with a special belt tension tool. As a safety precaution, always remove the negative battery cable when working near belts and pulleys. Do not take unnecessary chances. (Chevrolet)



Cutaway view of a 4.6-liter, SOHC (single overhead camshaft), V-8, gasoline engine. Depending on its application, this engine produces between 190 and 210 hp at approximately 4600 rpm. The engine incorporates cracked, powdered-metal connecting rods (rods have bearing caps cracked off instead of cut off); hydraulic cam chain tensioners; horizontal intake surfaces; aluminum heads; deep-mounted cylinder head bolts (improve seal and cylinder roundness); four-hole fuel injectors; an evaporative-cast, one-piece intake manifold; and a distributorless ignition system (DIS). (Ford)



Chapter 16

SERVICING ENGINE BLOCKS, CYLINDERS, PISTONS, RINGS, CONNECTING RODS

After studying this chapter, you will be able to:

☐ Check the condition of a cylinder block.
☐ Measure cylinder wear.
☐ Hone a cylinder wall.
☐ Describe cylinder reboring.
☐ Service automotive pistons.
☐ Properly install piston rings.
☐ Service connecting rods.
☐ Correctly install a piston and rod assembly in its cylinder.
☐ Measure bearing clearance with Plastigage.

ENGINE BLOCK

The engine block is the foundation on which the engine parts are assembled. Part alignment and wear demand that the block be free of distortion and cracks. The cooling system must be free of rust and scale. The oil galleries and internal surfaces must be clean.

CHECKING BLOCK FOR DISTORTION

In preparing to check the cylinder block for warpage or distortion, the first steps are dismantling and thorough cleaning. All parts should be cleaned down to the bare metal. This will allow close inspection and accurate measurement.

Check the cylinder block for warpage with a steel straightedge and feeler gauge as shown in Fig. 16-1. The surfaces should be true and flat within manufacturer's specs (about .003 in. or 0.08 mm in any 6 in. or 152 mm). If the distortion is not within these limits, the block will require resurfacing.

Fig. 16-2 shows how block surface can be trued up by grinding. A MINIMUM amount of metal should be removed. This will avoid changing the compression ratio, lifter-to-rocker arm distance, and piston-to-valve clearance.

Special head gaskets are available to compensate for removal of excessive head or block metal.

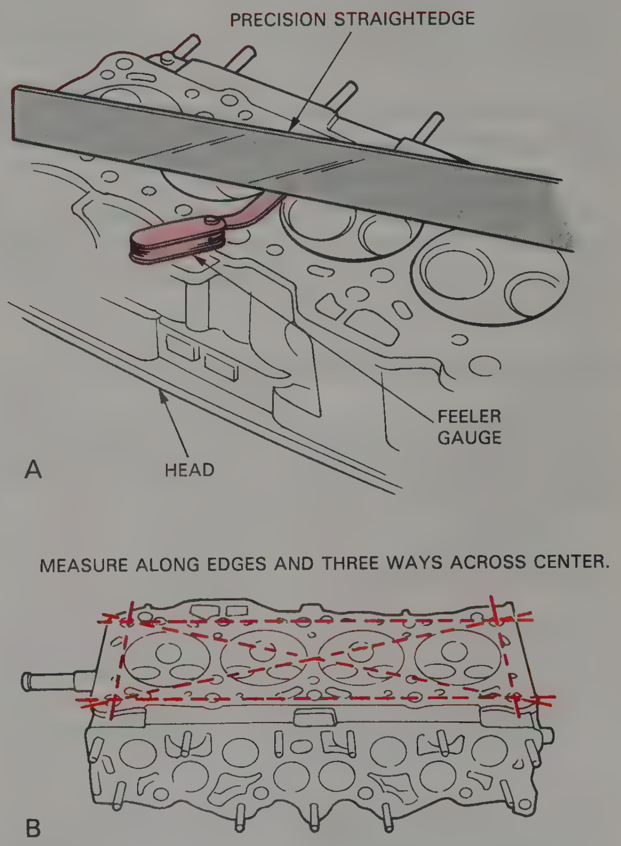


Fig. 16-1. A—Precision straightedge and feeler gauge are used to measure head distortion. B—One particular diagram indicating straightedge positions (dotted lines) for measuring. (Honda)

CHECK BLOCK FOR CRACKS

The block should be thoroughly checked for cracks. Pay special attention to the cylinders and the block area between the cylinders. See Chapter 8 for information on crack detection.

Replace all defective block core hole plugs. Refer to Chapter 19 on cooling system service for techniques.

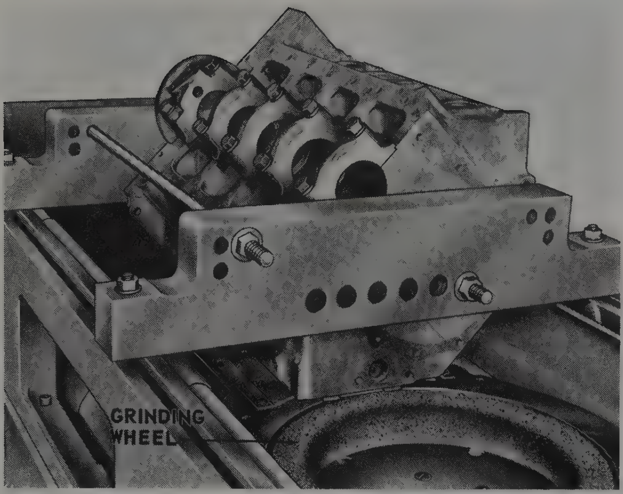


Fig. 16-2. Resurfacing block in grinder. (Van Norman)

CHECK CAMSHAFT AND MAIN BEARING BORE ALIGNMENT

The camshaft and main bearing bores should be checked for alignment. This procedure is covered in Chapter 15 dealing with camshafts and Chapter 14 covering crankshaft service.

REPAIR DAMAGED THREADS

Inspect all threaded holes for evidence of dirt, rust, scale, and stripped or galled threads. Repair as discussed in Chapter 3 on fasteners.

CYLINDER SERVICE

Engine cylinders, after long car usage, may become out-of-round and tapered to the extent that machining is required. Prior to reconditioning, however, the cylinder ring ridge must be removed. The cylinder must be inspected for cracks and scoring. Measure the amount of taper, out-of-roundness, and wear. Determine correct cylinder size.

TYPICAL CYLINDER WEAR PATTERN

Cylinder wear is heaviest in the upper portion. This is due to the pressure of the rings, intense heat, poor lubrication, combustion pressure, and abrasive material introduced to the combustion area through the air inlet system.

The bottom of the cylinder is lubricated better, is free of ring wear, and subjected to less piston thrust pressure. For this reason, the bottom area generally shows little wear. Wear in the upper portion of the cylinder, above ring travel, is also minor.

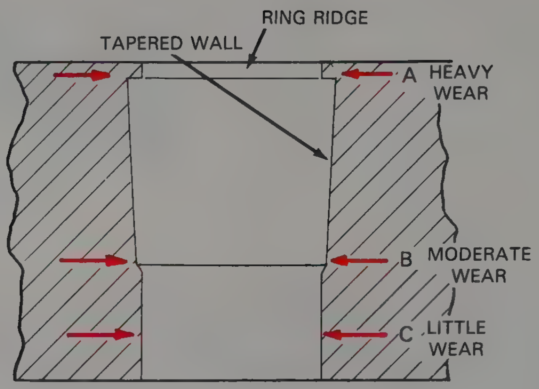


Fig. 16-3. Typical cylinder wear pattern. Diameter through A (top of ring travel), minus B (bottom of ring travel), indicates amount of taper. Note sharp edge formed by upper ring ridge. Ridge at bottom of ring travel is much less pronounced.

From Fig. 16-3, you will note that most wear is at the top of the ring travel. The heavy wear area extends downward about 3/4 to 1 in. (19.05 to 25.4 mm). Below this, there is a steady reduction in wear. This condition is known as TAPER.

The unworn area above the ring travel is referred to as the RING RIDGE. A similar ridge, much less pronounced, often exists at the bottom of the ring travel. See Fig. 16-3.

The normal cylinder will also wear out-of-round. The greatest wear will be at right angles to the engine or crankshaft centerline. This is primarily caused by the side thrust forces generated during the compression and firing strokes. Since the crankshaft connecting rod journal is offset to the line of piston travel, the piston attempts to move sideways, in addition to up or down. See Fig. 16-4.

RING RIDGE MUST BE REMOVED

Before pulling the pistons, the ring ridge must be removed. This will prevent the rings from striking the

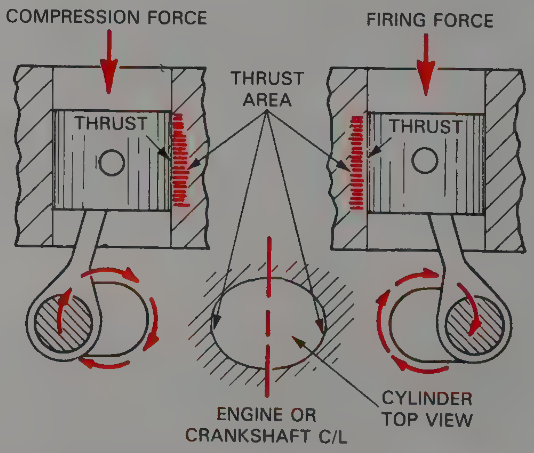


Fig. 16-4. Thrust forces wear cylinder out-of-round at right angles to engine centerline.

ridge and breaking either the rings, piston lands, or both.

Run the piston down in the cylinder. Wipe the cylinder and block surface with an oily rag and insert a suitable ridge reamer. One type is pictured in Fig. 16-5. Note the guide foot beneath the cutter to prevent undercutting the cylinder.

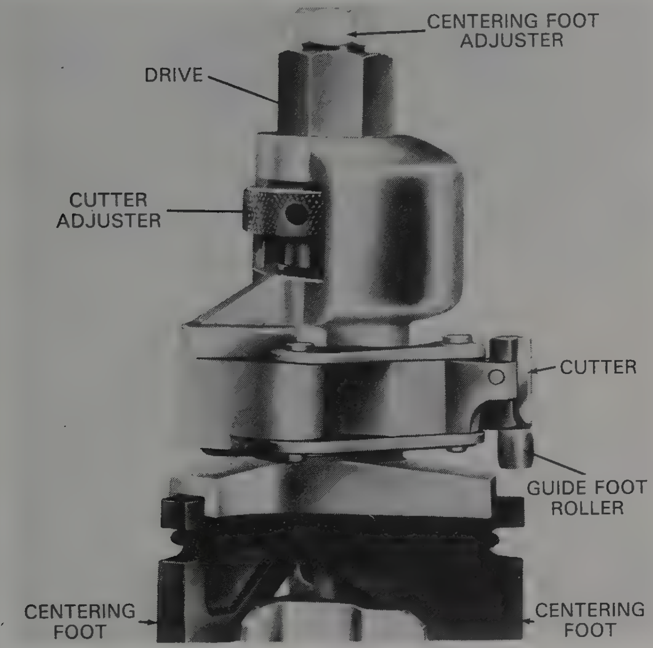

CENTERING FOOT ADJUSTER
DRIVE
CUTTER ADJUSTER
CUTTER
GUIDE FOOT ROLLER
CENTERING FOOT
CENTERING FOOT

Fig. 16-5. One type of cylinder ridge reamer. This reamer is supported by expanding centering feet against cylinder wall.

The ridge reamer should be expanded tightly in the cylinder. If it is the type shown in Fig. 16-6, a downward pressure should be exerted to keep the guide finger lips against the block surface. Turn the tool with smooth strokes. After each revolution, adjust the pressure to keep the cutter tight against the cylinder. This will help to prevent catching and making chatter marks. For cylinders that terminate in a tapered block surface, use a ridge reamer supported and aligned by the cylinder walls. See Fig. 16-6.

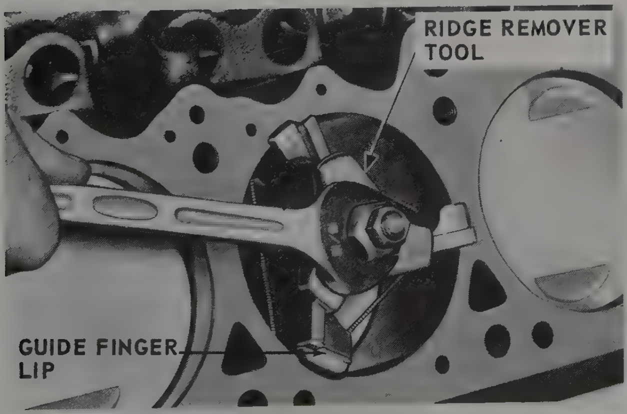

RIDGE REMOVER TOOL
GUIDE FINGER LIP

Fig. 16-6. Removing a ring ridge. This reamer is supported by lips on the top of the guide fingers. (Chrysler)

Stop cutting when the ridge has been removed. Be very careful to avoid CUTTING BELOW THE RIDGE INTO THE CYLINDER. The ridge area should blend smoothly into the cylinder proper, Fig. 16-7.

Fig. 16-8 shows how the ridge area should be blended into the cylinder.

INSPECT CYLINDERS

Following piston removal, wipe out the cylinders. Using a bright light, carefully inspect each cylinder for cracks and score marks. Heavy scoring (that a maximum rebore will not clean up) will require the installation of a sleeve. Cracking, depending on its location and severity, may also require sleeving.

Minor scoring and heavy scratches will require reboring to a suitable oversize. If the cylinder is smooth and wear is within limits, new rings will function properly following DEGLAZING (roughing cylinder to remove polished surface).

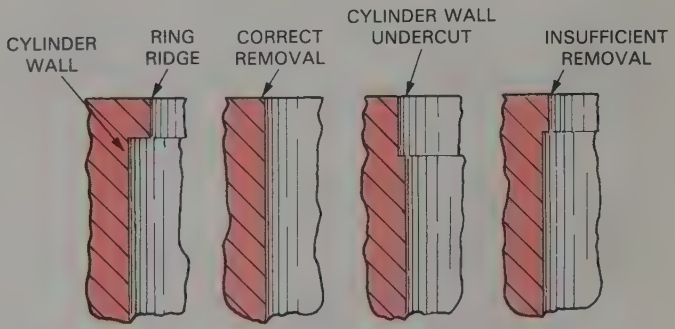

CYLINDER WALL
RING RIDGE
CORRECT REMOVAL
CYLINDER WALL UNDERCUT
INSUFFICIENT REMOVAL

Fig. 16-7. Ring ridge should be removed until ridge area is flush with cylinder wall.

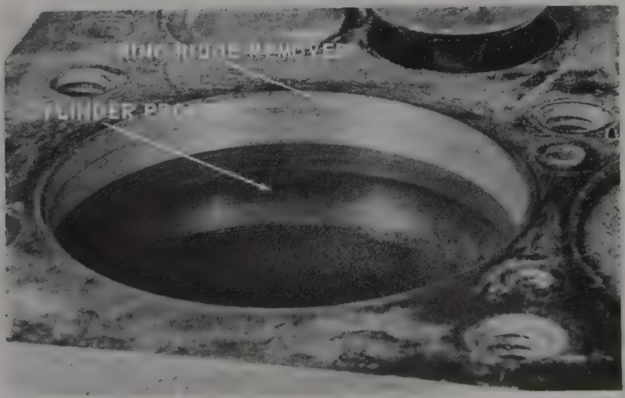


Fig. 16-8 Ring ridge area cut down until smoothly blended with cylinder proper. (Perfect Circle)

CHECKING CYLINDER DIAMETER

It is essential that the cylinder diameter be determined. This measurement will form the basis upon which new rings are ordered, and rebore sizes figured.

Carefully measure each cylinder at the bottom using an inside micrometer. Write down these measurements. Determine the original factory cylinder diameter. If your measurements are the same or not more than .009 in. (0.23 mm) larger, the cylinders are standard size. If your measurements are .010 to .019 in. (0.25 to 0.48 mm) larger, the engine has already been rebored to .010 in. (0.25 mm) oversize. If .020-.029 in. (0.51-0.74 mm) larger, it has been rebored to .020 in. (0.51 mm) oversize, etc.

For example, assume that your measurements show a cylinder diameter of 3.924 in. and the specifications list 3.910 in. as standard. The cylinder measurements are .014 in. larger than standard. This indicates that the engine was bored .010 in. oversize. The additional .004 in. would be wear in the lower area. See Fig. 16-9.

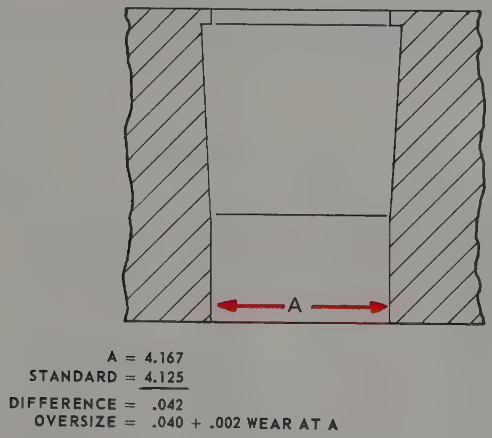


Fig. 16-9. Compare measurement A with factory standard to determine cylinder oversize.

Occasionally, the factory will, in order to salvage an otherwise sound block, bore the cylinders to oversize. When this is done, various markings are used to indicate such a condition. A factory rebored engine will generally have the amount of oversize stamped on the head of the pistons. Pistons, a trifle different in diameter (usually a few tenths of a thousandth), are individually fitted. The cylinder and piston both will then have size marks so the piston may be returned to the cylinder to which it was fitted.

CHECKING CYLINDER FOR TAPER AND OUT-OF-ROUND

It is important that each cylinder be checked for out-of-roundness and taper. A quick and accurate method is to use a cylinder dial gauge. Slide the gauge near the bottom of the bore and zero the indicator. Then, while keeping the guide feet in firm contact with the wall, slowly pull the indicator up through the cylinder. Slide the gauge up and down in several different sections and note the total indicator reading. This will determine the amount of taper.

Slide the gauge into the bore so the indicator stem is located in the area of ring wear. While holding the guide feet in firm contact, slide the gauge around in the bore. The indicator reading will show maximum out-of-roundness. Write down the readings for each cylinder, Fig. 16-10.

Another method, which is slower, is to measure the bore with an inside micrometer, Fig. 16-11. To do this, make two measurements near the bottom of the cylinder, one parallel to the engine centerline and the other

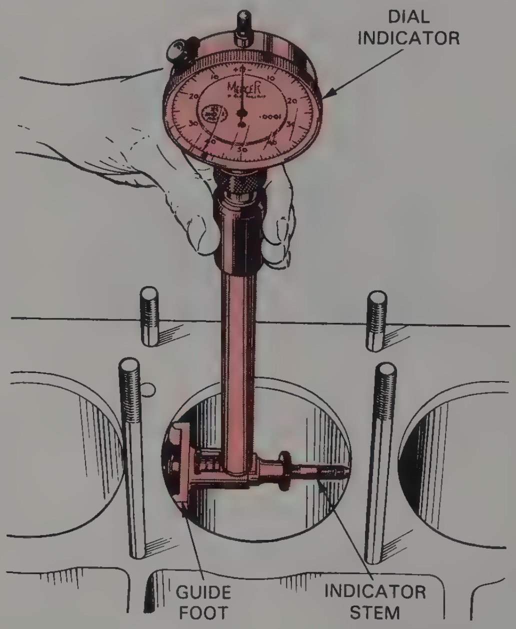


Fig. 16-10. Using a dial indicator cylinder bore gauge to check for cylinder taper and out-of-roundness. (British-Leyland)

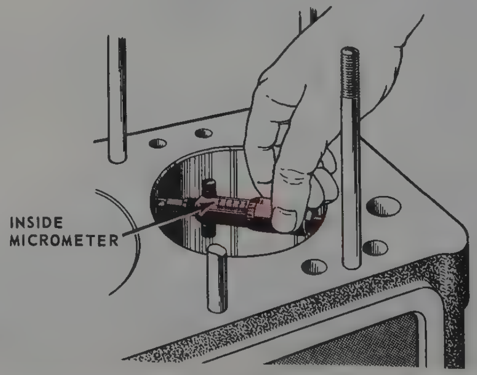


Fig. 16-11. Checking cylinder diameter with inside micrometer.

at right angles. Write them down. Make two similar measurements at the spot of greatest wear at the top of the cylinder. Be sure to make ACCURATE READINGS, Fig. 16-12.

The various readings may be listed as shown in Fig. 16-13 to facilitate taper and out-of-roundness computations. Be certain to indicate the number of the cylinder concerned.

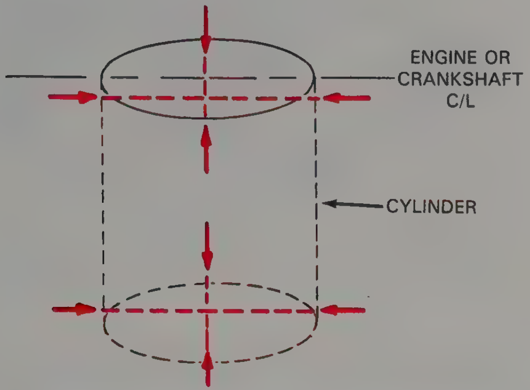


Fig. 16-12. Measure each cylinder at these points.

CYLINDER NUMBER	1	2	3
TOP R/A	3.885		
TOP C/L	3.880		
OUT-OF-ROUND	.005		
TOP R/A	3.885		
BOT. R/A	3.8765		
TAPER	.0085		
BOT. R/A	3.8765		
STANDARD	3.875		
OVERSIZE	.0015		

(R/A = MEASUREMENT AT RIGHT ANGLES TO ENGINE CENTERLINE)
(C/L = MEASUREMENT ALONG ENGINE CENTERLINE)

Fig. 16-13. Cylinder measurements may be listed in this manner to facilitate out-of-roundness, taper, and oversize computations.

PERMISSIBLE TAPER

If the cylinder is not scored, cracked, or scuffed, an amount of taper up to a maximum of .012 in. (0.30 mm) is usually permissible. Taper beyond this point will require reboring to correct.

As taper increases, ring efficiency drops off. Ring float and tipping will destroy the seal and can cause rings to break as well as to scuff the cylinder wall.

Rings, to function properly, must follow the cylinder wall. When taper is excessive, the rings are compressed at the bottom of their travel. At high rpm, the piston will travel to the top of the cylinder and, before the rings have a chance to expand outward in the wider upper section, the piston starts down. This leaves the rings literally floating at the top of their travel. See Fig. 16-14.

As the piston enters the enlarged upper cylinder area, it will tip back and forth. This causes both the upper and lower ring edges to round off. Sealing efficiency is lost and scuffing can occur, Fig. 16-15.

The piston, in addition to tipping, will be slammed from one side of the cylinder to the other as the crankshaft rod journal passes over TDC (top dead center). This produces a noise called "piston slap." In addition to ring damage, the piston can fatigue and literally disintegrate.

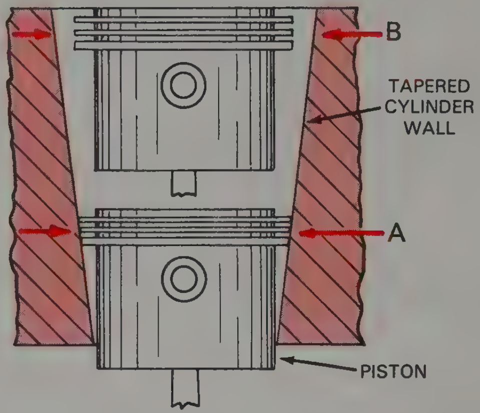


Fig. 16-14. Excessive cylinder taper causes ring "float." Note how rings contact cylinder wall at A, but before they can expand outward at B, the piston starts down again.

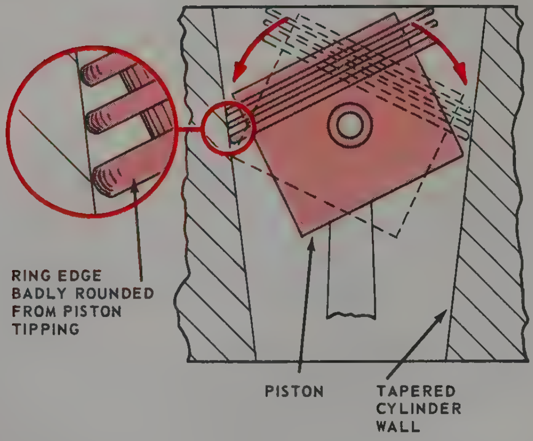


Fig. 16-15. Piston loose in bore allows tipping (exaggerated in drawing). This will produce rounded ring edges, thus destroying their efficiency.

CYLINDER OUT-OF-ROUNDNESS

Cylinder out-of-roundness should not exceed .005 in. (0.13 mm). Beyond this point it is not possible for the rings to conform to the cylinder wall. Heavy oil burning will result. Some manufacturers, due to differences in engine design and application, specify even less than a maximum of .005 in. (0.13 mm). Always follow the manufacturer's specifications, Fig. 16-16.

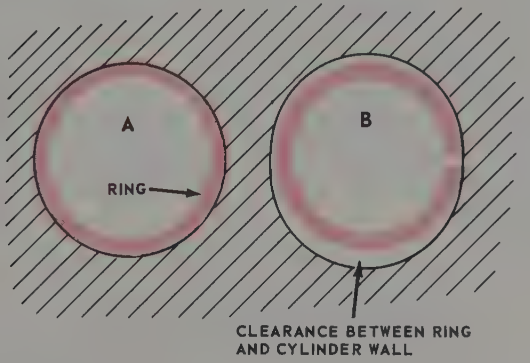


Fig. 16-16. Rings cannot conform to cylinders exceeding .005 in. or 0.013 mm out-of-roundness. A—Cylinder is round. B—Note poor ring fit in out-of-round cylinder.

CYLINDER WALL SURFACE MUST ASSIST BREAK-IN OR SEATING

A shiny, glazed surface on the cylinder wall, if not removed, will cause the time for "break-in" (rings wearing enough to seat or conform to walls) to become excessive. In some cases, the rings may never seat properly.

Deglazing, although discouraged by a few manufacturers, is commonly accepted as good practice IF:

1. Honing is not excessive.
2. The correct micro inch surface is imparted.
3. The cylinders are thoroughly CLEANED following honing.

New rings have minute tool thread marks around the ring-to-cylinder edge. The cylinder wall should also have minute scratches imparted by the hone. As the new rings travel up and down, both the cylinder wall and rings will wear a tiny amount. High spots on the ring will tend to wear off allowing the low spots to contact the wall.

The correct cylinder wall micro inch finish is one that will allow the rings to seat at about the same time the cylinder wall has returned to its glazed condition. A wall finish that is too rough will wear the rings excessively. A finish that is too smooth can prolong or even prevent seating. A properly seated ring will retain some thread marks for thousands of miles. See Fig. 16-17.

HONE GRIT SIZE FOR CORRECT MICRO INCH FINISH

Finishing stones with grit sizes of 180 and 220 will produce finishes of around 20-30 and 15-25 micro inches (millionths of an inch) respectively, which are satisfactory. Equipment for checking in micro inches is NOT available in most shops, however.

The micro inch finish, for any given stone, can be controlled by varying the pressure of the stones against the wall. A light pressure will produce a finer finish. Heavy pressure will cause the abrasive particles to cut deeply, producing a rougher surface. Light to medium pressure is recommended.

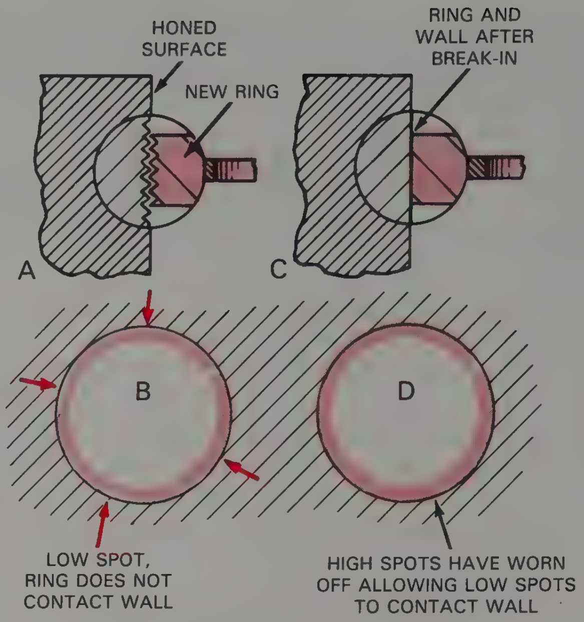

HONED SURFACE
NEW RING
RING AND WALL AFTER BREAK-IN
A
C
B
D
LOW SPOT, RING DOES NOT CONTACT WALL
HIGH SPOTS HAVE WORN OFF ALLOWING LOW SPOTS TO CONTACT WALL

Fig. 16-17. Cylinder wall surface must insure proper ring seating. New ring operating against honed surface will break-in correctly. A—Honed cylinder and new ring. B—Ring does not fit cylinder perfectly when new. C—Engine operation and friction wear off hone marks. D—Ring break-in makes ring seal properly.

DEGLAZING CYLINDERS WITH MINOR WEAR

Cylinders with minor taper and out-of-roundness can be deglazed by using a spring-loaded hone such as shown in Fig. 16-18 or a special abrasive tipped wire deglazer. These are available in a variety of different sizes, Fig. 16-19.

Cover the crankshaft with rags. Swab some honing oil on the walls. Insert the hone. Using a suitable electric drill for power, start the hone spinning. Move the hone up and down in the cylinder. Do not let stones protrude more than 1/2 in. (12.7 mm) on top or bottom. Move rapidly enough to produce a cross-hatch finish similar to that shown in Fig. 16-20. Note that the cross lines form an included angle of about 50 deg. Do not be too concerned about an exact angle. Anything from 20 to 60 deg. will suffice.

Make about 12 complete strokes with the hone. Wipe the bore and inspect the walls.

If a hone pattern is visible over most of the ring travel

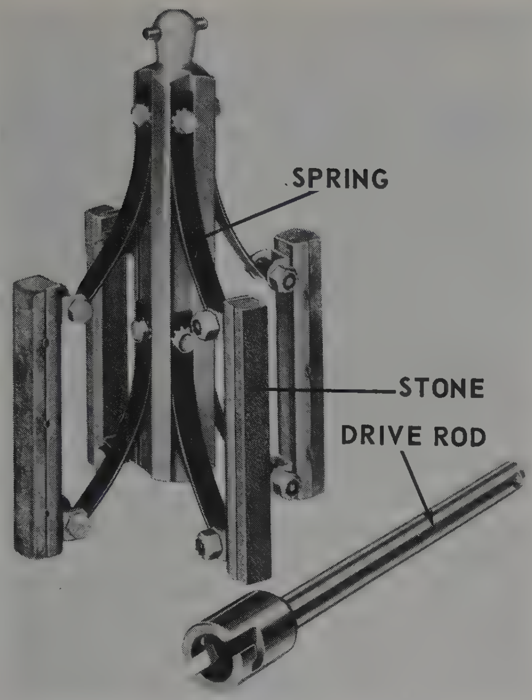


Fig. 16-18. Typical spring-loaded deglazing hone.

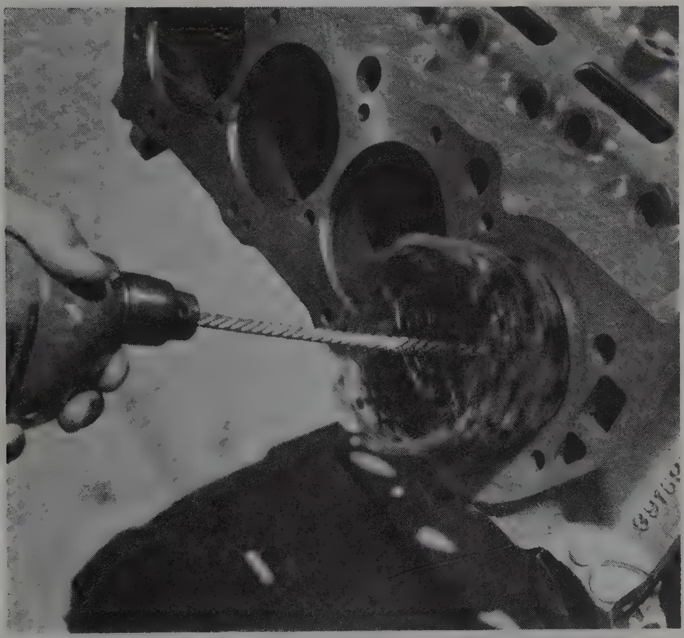


Fig. 16-19. One type of abrasive tipped cylinder hone. They are available in many different sizes, shapes, and lengths. (Goodson)

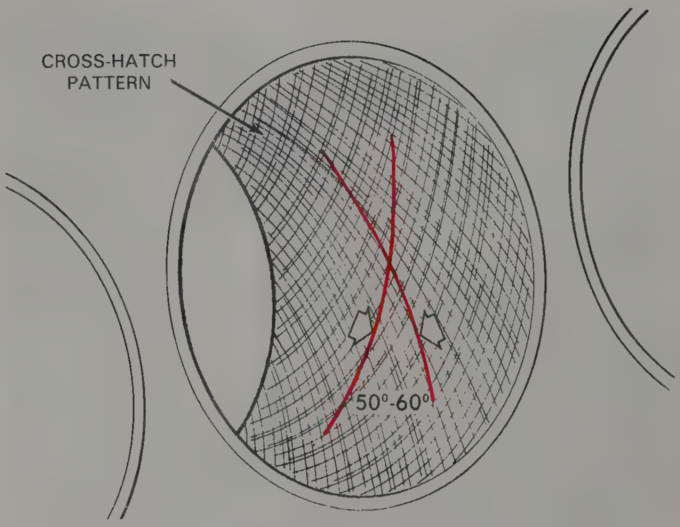


Fig. 16-20. A spring-loaded hone was used to create this desirable cross-hatch pattern. (Chrysler)

area (a narrow band at point of heaviest wear need not be honed), consider the cylinder finished. If not visible, repeat and check again.

HONING CYLINDERS WITH PRONOUNCED WEAR

When cylinder wear has almost reached maximum acceptable taper and out-of-roundness, the adjustable RIGID HONE should be used, Fig. 16-21. This type of hone will not flex to fit the wall taper and will tend to remove both taper and out-of-roundness.

Cover the crankshaft. Apply honing oil. Insert the hone in the BOTTOM of the bore. Use 180 or 220 grit stones. Adjust the stones outward until firm, but not too tight, contact with the cylinder wall is obtained. Drive the hone with a 1/2 or 3/4 in. electric drill.

THIS TYPE OF HONE REQUIRES CONSIDERABLE TORQUE TO START. GRASP THE DRILL HANDLES TIGHTLY. KEEP YOUR CLOTHING AWAY FROM THE SPINNING HONE.

Start honing the bottom of the cylinder first. Use short up and down strokes. In that the cylinder walls at the bottom are the least worn, they will keep the

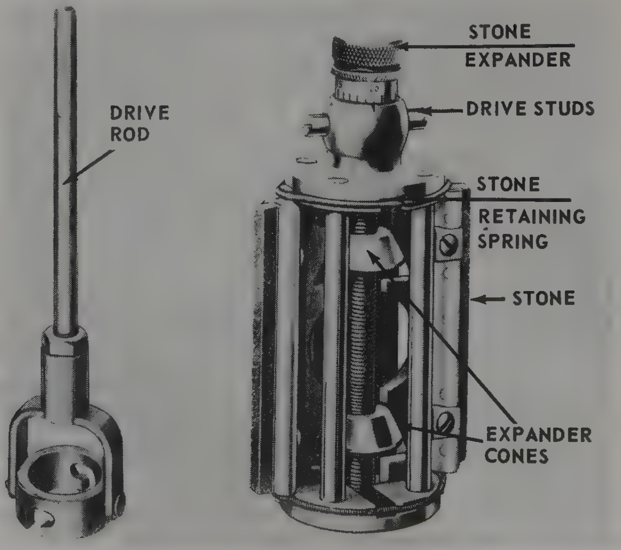


Fig. 16-21. One type of rigid hone. (Lisle)

hone properly aligned.

Keep adjusting the hone to assure firm stone to wall contact. After approximately twenty short, fast strokes, loosen the stones. Withdraw the hone and inspect the cylinder. As soon as the hone marks cover about 70 percent of the bore, stroke the hone the full length of the cylinder. Try for a cross-hatch pattern as mentioned.

NEVER PULL THE HONE OUT OF THE CYLINDER WHILE SPINNING—PARTS CAN REALLY FLY.

Allow the stones to protrude about 1/2 in. (12.7 mm) above and below. Do not strike the crankshaft. Before starting the hone, it should be pushed down the desired depth and the relationship between the stone drive and the top of the cylinder studied. This will assist in determining when the proper depth has been reached. Fig. 16-22 illustrates the honing sequence.

Use of the rigid hone as described will necessitate expanding the old pistons or using oversize pistons and rings in order to secure a suitable working clearance between piston and cylinder. This will be discussed later in this chapter.

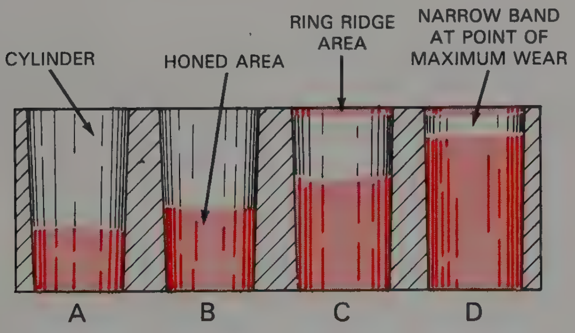


Fig. 16-22. Hone pattern sequence. Hone started in bottom of cylinder (A). As honing progresses, cross-hatch covers more and more of the bore. (B, C, D).

REBORING CYLINDERS

When cylinders have exceeded wear limits or when heavy scoring is present, they should be rebored to a suitable oversize. Ideally, all cylinders should be bored to the same size.

DETERMINING SUITABLE OVERSIZE

After careful measurement of all cylinders, compute the amount of oversize necessary to "clean up" the worst one. Do not overlook scoring. Reboring is done in multiples of .010 in. (0.25 mm). Oversizes of .010, .020, .030, and .040 in. (0.25, 0.51, 0.76, and 1.01 mm) are most commonly used.

Do not try to clean up all cylinders with an oversize that is just barely larger than the poorest cylinder. Small variations in boring bar centering may leave areas untouched. By the same token, do not use excessive oversizes unless desired to raise displacement for performance. By using the smallest practical oversize, correction for wear in the future will still be possible. Some aluminum blocks use cast-in sleeves that are relatively THIN. On these installations it is especially important to remove a minimum amount of metal.

SETTING UP BORING BAR

There are numerous types of boring bars, ranging from fairly portable to massive production type units. In using this equipment, always follow the manufacturer's directions.

The face of the block (some bars do not attach to block) should be draw filed. Center the bar carefully in the cylinder. Because the bottom is the least worn, it is advisable to center in this area. Following centering, the bar should be firmly clamped to the block, Fig. 16-23.

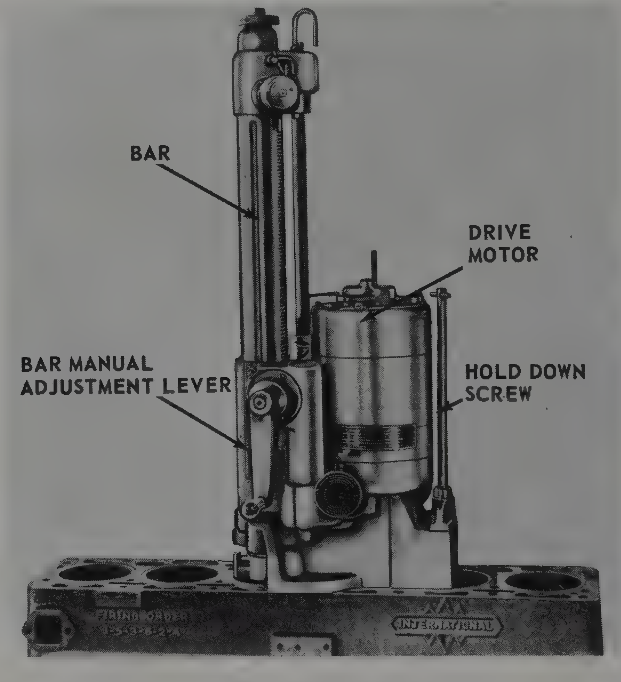


Fig. 16-23. Boring bar set up on an engine block. (Van Norman)

BORING THE CYLINDER

The cutter must be kept SHARP. It should be carefully set to cut a hole that will be .0025 in. (0.064 mm) smaller than the finished size. This allowance is for honing the cylinder to remove boring tool marks, fractured metal, and to impart the correct micro inch finish.

FOLLOWING BORING, HONING IS A MUST. A VERY SMOOTH BORED SURFACE WOULD

STILL BE IN A 60-70 MICRO INCH RANGE. THIS IS FAR TOO ROUGH FOR PROPER RING SERVICE.

It is considered good practice to bore alternate cylinders. The boring cut heats up the cylinder. If the adjacent cylinder is bored next, there is a chance that the hole, upon cooling, will be distorted.

Back off the cutter before withdrawing from the finished cylinder. The sharp edge at the top of the cylinder must be chamfered by hand feeding the bar. Remember that accurate centering, firm clamping, sharp tools, and exact cutter settings are essential. Mike each bore for size and use a cylinder dial gauge to check for taper or out-of-roundness.

Another type of boring bar is shown in Fig. 16-24. Note that it is not attached to the block surface.

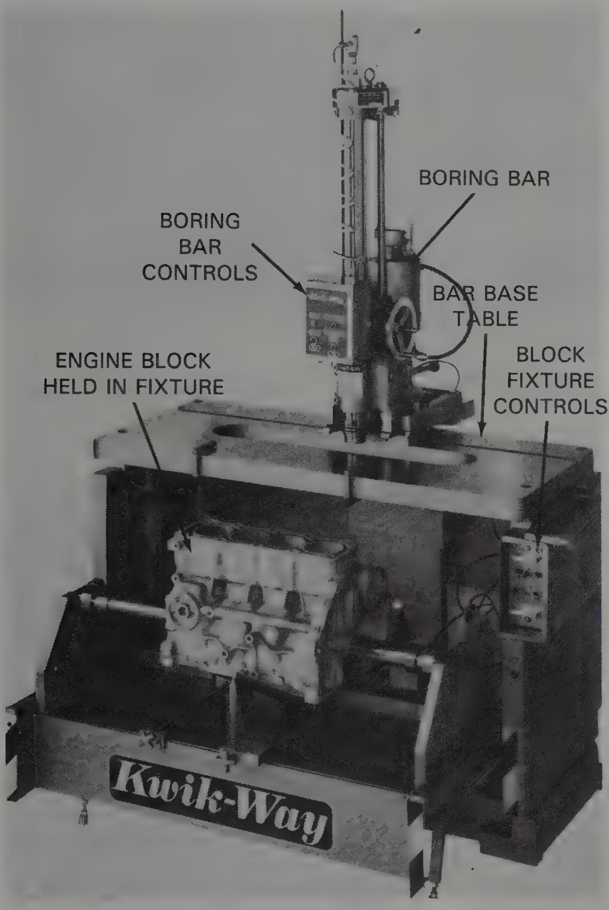


Fig. 16-24. Boring bar. Note that this bar is not directly attached to block.

INSTALLING CYLINDER SLEEVE

A cylinder, otherwise ruined, can often be salvaged by installing a sleeve and then boring to size. Maximum bar cuts should be around .050 in. (1.27 mm). Take several cuts. When near proper size, use a light finishing cut. Follow specifications for sleeve fit to block. Fig. 16-25 shows a sleeve being forced into place.

HONING FOLLOWING BORING

Use a RIGID type hone with 180 or 220 grit stones. Hone the full length of the bore to produce a correct cross-hatch finish. Hone until the new piston is correctly fitted (see section on piston service). If the desired .0025 in. (0.064 mm) of material was removed following boring, a satisfactory base metal (final finish produced in solid, unfractured block metal) finish will result.

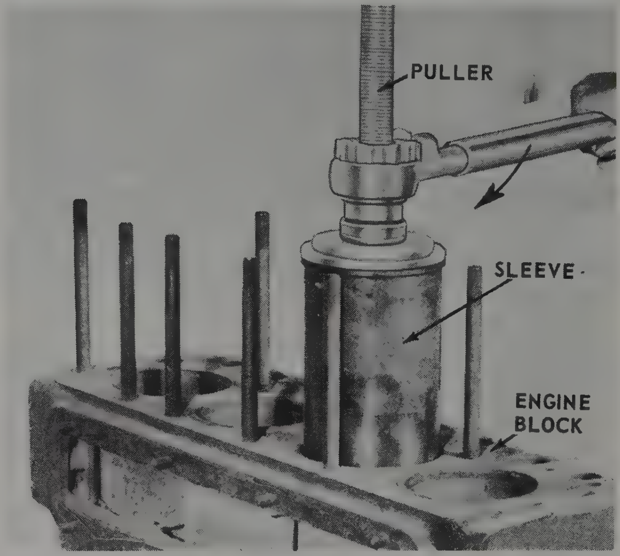


Fig. 16-25. Using a puller to draw a cylinder sleeve into place. (O.T.C.)

CLEANING CYLINDERS FOLLOWING HONING

THOROUGH CLEANING FOLLOWING HONING IS OF VITAL IMPORTANCE. Do not use gasoline, kerosene, cleaning solvent, or oil. Use HOT, SOAPY WATER AND A STIFF BRISTLE (NOT STEEL) BRUSH. SCRUB. RINSE. SCRUB AND RINSE AGAIN. FOLLOW WITH A HOT, CLEAR WATER RINSE, IMMEDIATELY WIPE CYLINDERS DRY AND SWAB WITH CLEAN ENGINE OIL.

This procedure will remove abrasives and minute metal particles. The crankshaft, if in place, must be cleaned, dried, and the journals oiled. Check areas of the crankcase under the cylinders carefully. Clean thoroughly.

Despite a fine job of cylinder reconditioning, piston and ring fitting, the whole job may be destroyed if cleaning is not thorough. Fig. 16-26 shows a mechanic drying the cylinders following the final hot water rinse.

Fig. 16-26. Cylinders must be thoroughly cleaned following honing.

PISTON SERVICE

Pistons must be of the correct type, weight, and size. They must be free of cracks, scoring, burning, and damaged ring grooves. They must be properly fitted to the cylinders, rings, and piston pins.

CLEANING PISTONS

Following removal of the pistons from the engine (see section on connecting rod service following in this chapter), remove the rings and soak the piston and rod assembly in a good carbon removing solvent. Rinse and dry.

Clamp the connecting rod LIGHTLY in a vise with the piston skirt just clearing the jaws. Clean any remaining carbon from the ring grooves. Be careful to avoid cutting any metal from either the side or the bottom of the grooves. Fig. 16-27 illustrates one type of ring groove cleaner.

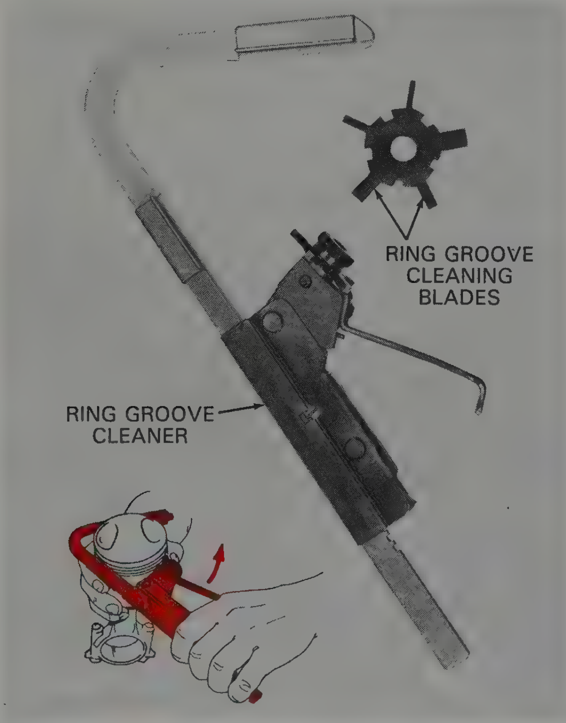


Fig. 16-27. Cleaning piston ring grooves with one type of hand held tool. Note different blade sizes. (Lisle Tool)

CHECK RING GROOVES

Examine all ring grooves for burrs, dented edges, and side wear. Pay particular attention to the top compression ring groove. It is the one most subject to wear, Fig. 16-28.

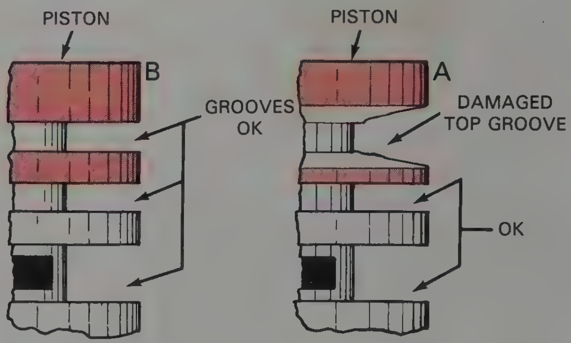


Fig. 16-28. A—Badly damaged top ring groove. B—Normal groove. Compare two.

Groove width can be checked by sliding a new ring into the groove and using a feeler gauge to determine clearance, (see section on ring service). Check at several spots around the groove. Special gauges are also available for a quick check of groove wear. The gauge shown in Fig. 16-29 has several lips that are .006 in.

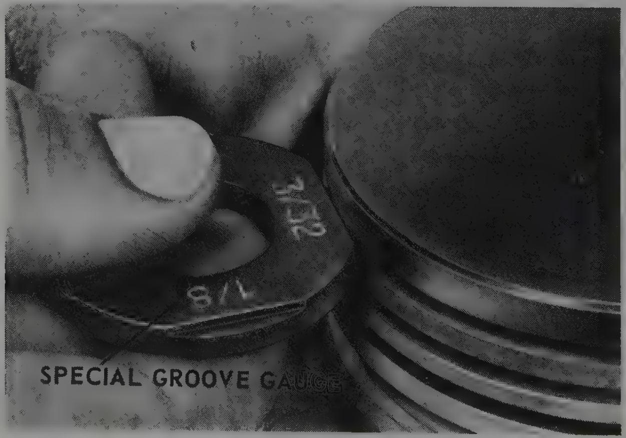


Fig. 16-29. Checking ring groove width with special gauge. (Perfect Circle)

(0.15 mm) larger than the standard grooves for which they are designed. If the lip will enter the groove, clearance is excessive and the groove needs to be reconditioned.

RECONDITIONING A RING GROOVE

The ring groove can be reconditioned by cutting the groove wider and installing a steel spacer on the top edge. The groove reconditioning tool, Fig. 16-30, drives the piston with a lathe. Hand driven tools are also available. See Fig. 16-31.

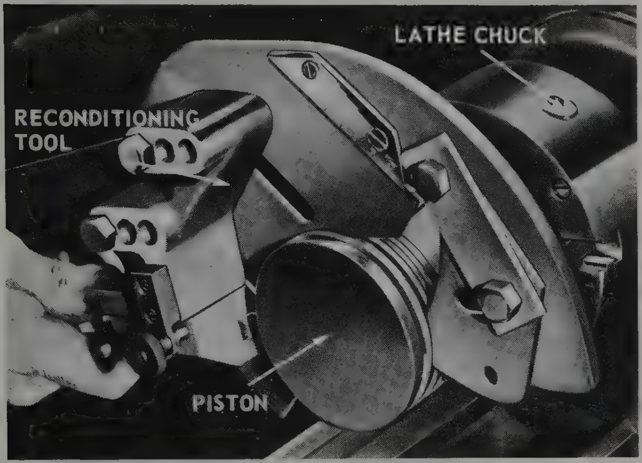


Fig. 16-30. Reconditioning top ring groove using power driven setup. (Sealed Power)

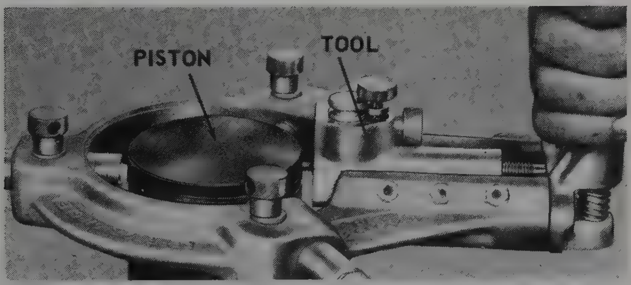


Fig. 16-31. Reconditioning top ring groove with a hand operated tool.

One popular method of affixing the steel spacer is shown in Fig. 16-32.

Fig. 16-33 shows how failure to repair a top ring groove caused excessive ring play that ruined the piston.

CHECK PISTONS FOR CRACKING, SCUFFING, BURNING, AND SCORING

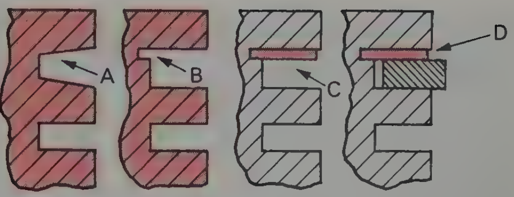


Fig. 16-32. Steps in repairing worn top ring groove. A—Worn groove. B—Groove widened and spacer section notched. C—Spacer installed. D—Ring fits as specified.

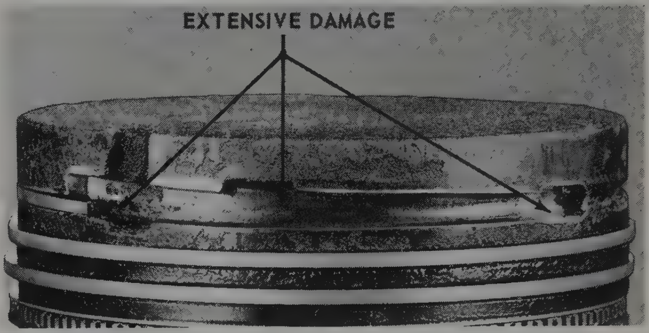


Fig. 16-33. Excessive ring groove wear ruined this piston.

Check each piston for signs of cracking. Pay particular attention to the piston pin bosses and skirt (see section on crack detection). ANY CRACKING, NO MATTER HOW SMALL, IS CAUSE FOR REJECTION. The piston cutaway in Fig. 16-34 shows cracks in both pin bosses. Also note damaged snap ring grooves.

Burning is sometimes severe, as pictured in Fig. 16-35.

Installation with insufficient clearance caused the heavy scoring on the thrust side of the piston in Fig. 16-36.

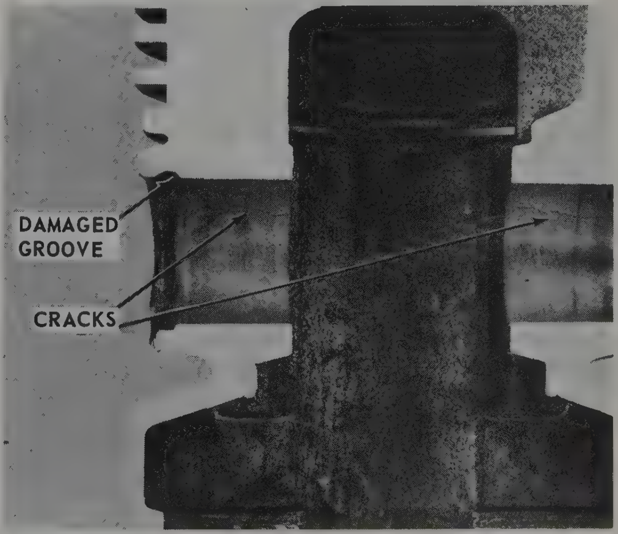


Fig. 16-34. Note cracked pin bosses and damaged snap ring grooves. (Sunnen)

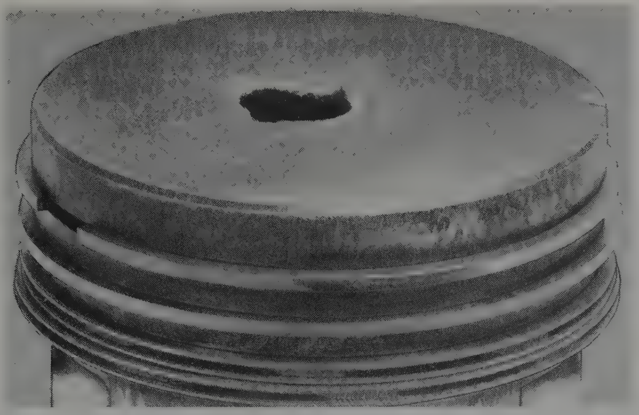


Fig. 16-35. Preignition burned hole through head of this piston. (Perfect Circle)

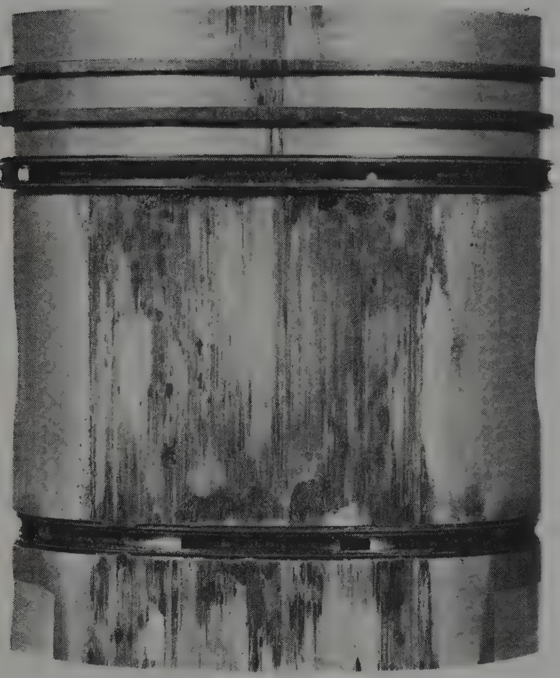


Fig. 16-36. Insufficient clearance caused heavy scoring and scuffing on this piston.

Scuffing is caused by metal-to-metal contact. Excessive heat will build up and particles will be torn from one surface and deposited on another. Scuffing and scoring are closely related.

Scuffed areas will generally be discolored by the effects of the heat generated.

When pistons show signs of corrosion, look carefully for possible coolant leaks—cracked head or cylinder, warped head or block, damaged gasket, or other problem. The piston illustrated in Fig. 16-37 was badly corroded by coolant.

REJECT PISTONS SHOWING ANY SIGNS OF BURNING, SCUFFING, SCORING, CORROSION, OR CRACKING.

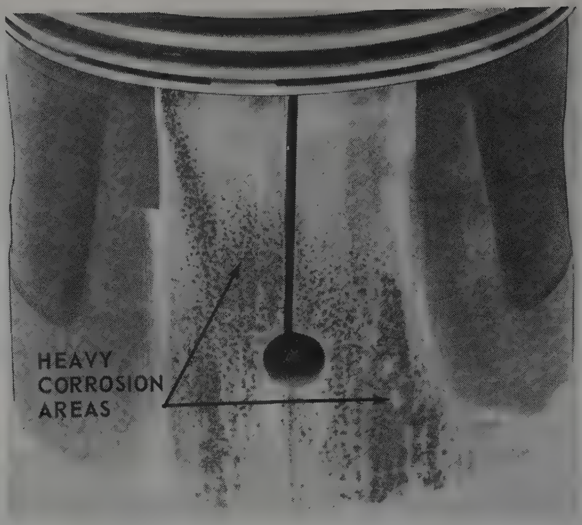


Fig. 16-37. Coolant leakage caused corrosion on skirt of this piston.

RESIZING PISTONS

If the old pistons are to be used on reconditioned cylinders, they should be resized or expanded to provide proper fit in the cylinders. Normal cylinder wear plus piston wear may leave the pistons loose enough in the cylinders to cause tipping. Tipping will round ring faces, rendering them useless. This looseness will also cause the noise referred to as "piston slap."

One way to resize pistons is to have the thrust areas of the skirts knurled—trade names for process vary. The piston (rod may be left attached in most cases) is placed in a special machine. While supporting the inner portion of the skirt, the machine rolls (knurls) a series of narrow dents into the piston outer surface, Fig. 16-38.

The piston metal around the dents forms a series of raised areas that increase piston diameter. Instructions

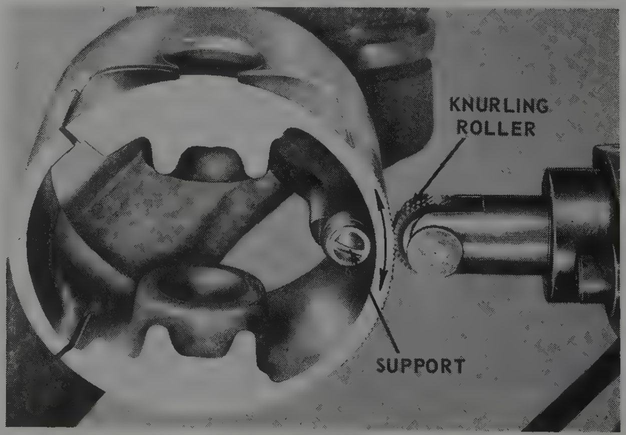


Fig. 16-38. Cutaway piston showing knurling roller in action. (Perfect Circle)

supplied by the manufacturer should be followed carefully. See Figs. 16-39 and 16-40.

The knurled grooves retain oil for excellent lubrication and act as traps for minute metal particles that would otherwise cause scoring.

Other resizing techniques such as shot peening, cold expanding followed by heating and quenching, or installing spring skirt expanders are also used.

FITTING PISTONS TO CYLINDERS

New or resized pistons must be checked for proper clearance in the cylinder. In the case of resized (knurled) pistons, the knurled area can be wire brushed to produce a desired fit. New pistons require that the cylinder bore be honed until the piston clearance is correct.

An oiled, long feeler gauge strip is placed in the bore, the piston inverted and shoved down into the bore so that the skirt thrust surface bears against the strip. A spring scale is attached to the feeler and the feeler strip withdrawn. Specifications supplied by the manufacturer will indicate the correct pull in pounds (kilograms) for specific feeler thickness. See Fig. 16-41.

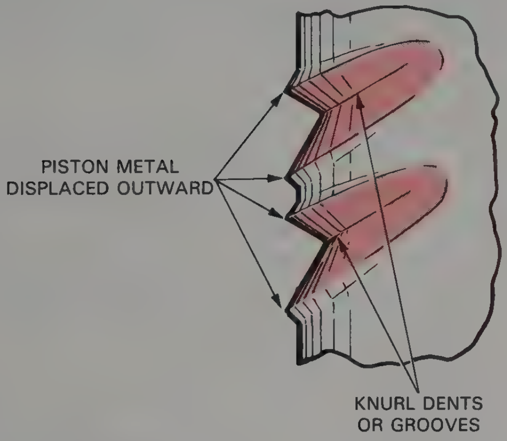


Fig. 16-39. Knurling displaced piston metal thus effectively widening skirt diameter.

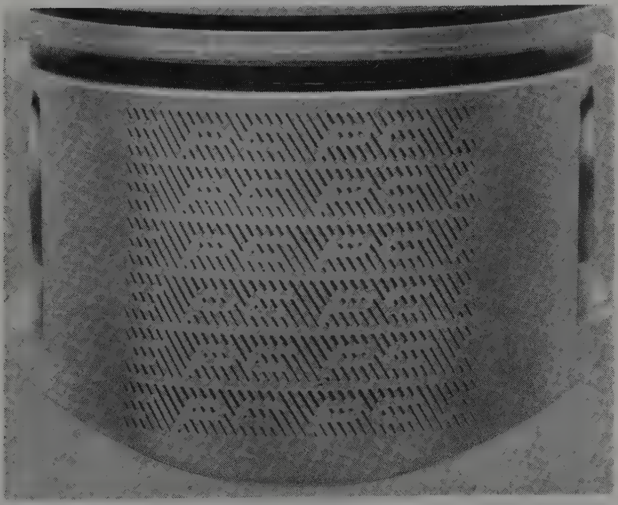


Fig. 16-40. Complete knurl pattern on piston skirt.

In worn cylinders, the check should be made near the bottom (area of smallest diameter).

Piston-to-cylinder clearance may also be determined by careful measurement of both piston and cylinder (smallest diameter). Measure the piston at both top and bottom of the skirt across the thrust surfaces. Some manufacturers specify an exact location for piston measurement. Measurements should be taken when metal is at room temperature, 60 to 70 °F (16 to 21 °C).

Once a piston is properly fitted, it should be marked for the cylinder concerned. Clearances with .001 to .0015 in. (0.025 to 0.038 mm) are about average.

PISTON PINS

Piston pins can be designed to oscillate in the connecting rod, in the piston, or in both. Fig. 16-42 illustrates five pin arrangements.

PIN FIT

Piston pin fit (clearance between pin and bearing surface) is IMPORTANT. A pin must have ample clearance for oil, yet it must not have looseness that will result in "pin knock" and ultimate failure. The bearing surfaces must be ROUND, SMOOTH, STRAIGHT, AND IN PERFECT ALIGNMENT, Fig. 16-43.

CHECKING PIN FIT—USED PISTON AND PIN

Clamp the connecting rod lightly in a vise. Attempt to rock the piston on the pin. Any discernable

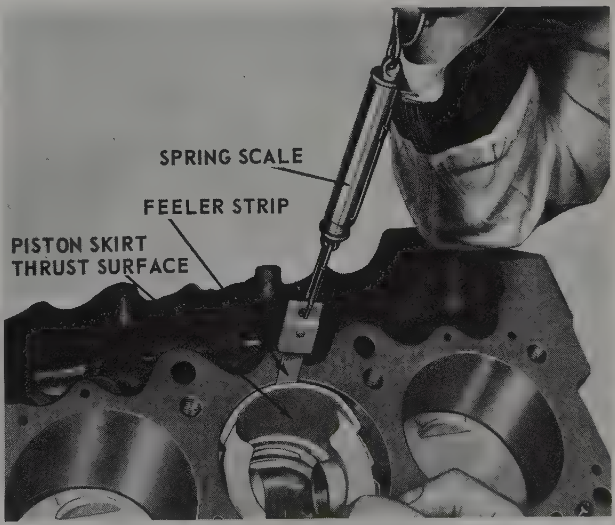


Fig. 16-41. Checking piston-to-cylinder clearance with a feeler strip and spring scale. (Plymouth)

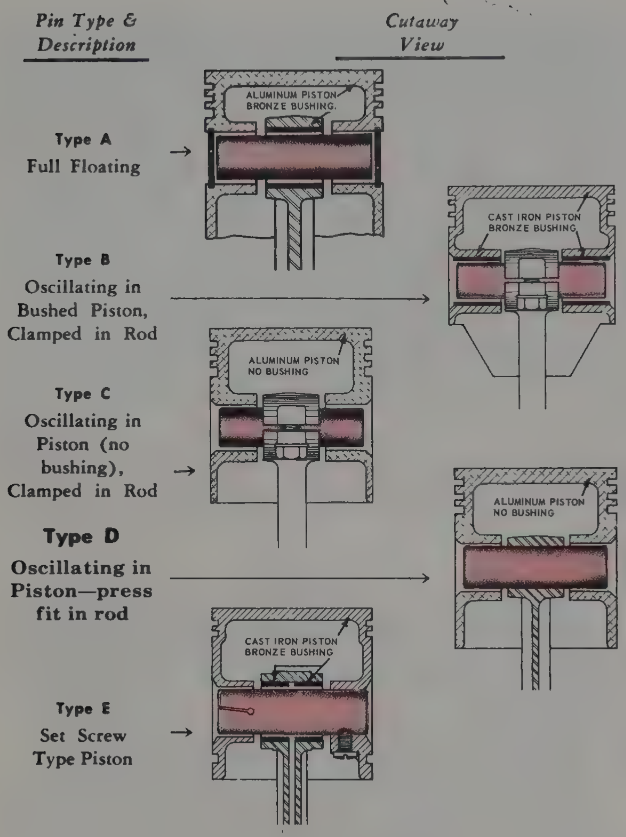

Pin Type & Description
Cutaway View
Type A
Full Floating
ALUMINUM PISTON BRONZE BUSHING
Type B
Oscillating in Bushed Piston, Clamped in Rod
CAST IRON PISTON BRONZE BUSHING
Type C
Oscillating in Piston (no bushing), Clamped in Rod
ALUMINUM PISTON NO BUSHING
Type D
Oscillating in Piston—press fit in rod
ALUMINUM PISTON NO BUSHING
Type E
Set Screw Type Piston
CAST IRON PISTON BRONZE BUSHING

Fig. 16-42. Various piston pin arrangements. Type D is currently in wide use. (Sunnen)

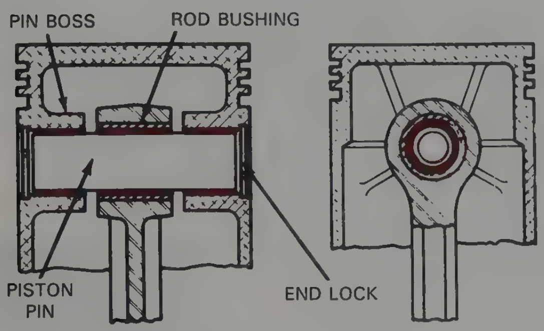

PIN BOSS
ROD BUSHING
PISTON PIN
END LOCK

Fig. 16-43. An accurately fitted pin will provide proper and uniform oil clearance both in piston bosses and in rod bushing (where used).

movement (do not confuse sliding along pin with up-and-down movement) between pin and piston or pin and rod is cause for pin rejection. Careful measurement of pin and boss, using a vernier micrometer and a small hole gauge will determine exact clearance. See Fig. 16-44.

To compensate for excessive wear, it will be necessary to install an oversize pin and, in some instances, new bushings. If the pin is bushed in the rod or piston and the bushing shows only minor wear, the old bushings may be honed to fit the oversize pin.

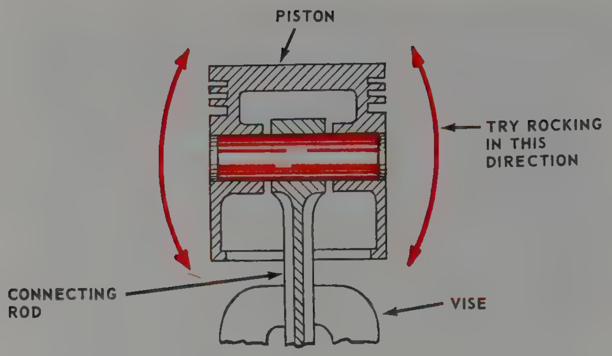

PISTON
TRY ROCKING IN THIS DIRECTION
CONNECTING ROD
VISE

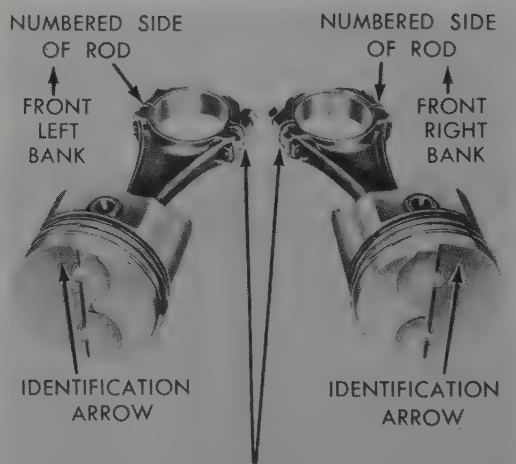
Fig. 16-44. There should be no discernable movement between piston or connecting rod and piston pin.

PISTON PIN REMOVAL

Before removing the piston pin, make certain the piston is marked so that it may be reassembled to the SAME rod in the SAME position. Prick punch marks will suffice if no factory identification has been provided. Fig. 16-45 illustrates one type of factory identification.

If the piston pin is the floating type, remove the end locks (snap rings) and tap the pin free. Do not mar the piston pin bearing area. Use care in removing the end locks so as not to distort them.

Most engines are currently using a pin that oscillates in the piston and is a press fit in the rod. With this type, use a press or puller arrangement, such as shown in Fig. 16-46, to remove the pin.


NUMBERED SIDE OF ROD
FRONT LEFT BANK
NUMBERED SIDE OF ROD
FRONT RIGHT BANK
IDENTIFICATION ARROW
IDENTIFICATION ARROW

POSITION OIL SQUIRT HOLE INWARD WITH PISTON IDENTIFICATION ARROW FORWARD TOWARD FRONT OF ENGINE. CAUTION: PISTONS ARE NOT INTERCHANGEABLE FROM ONE CYLINDER BANK TO THE OTHER.

Fig. 16-45. Factory identification marks are used to insure correct relationship between piston, connecting rod, and block, for one specific engine. (Lincoln)

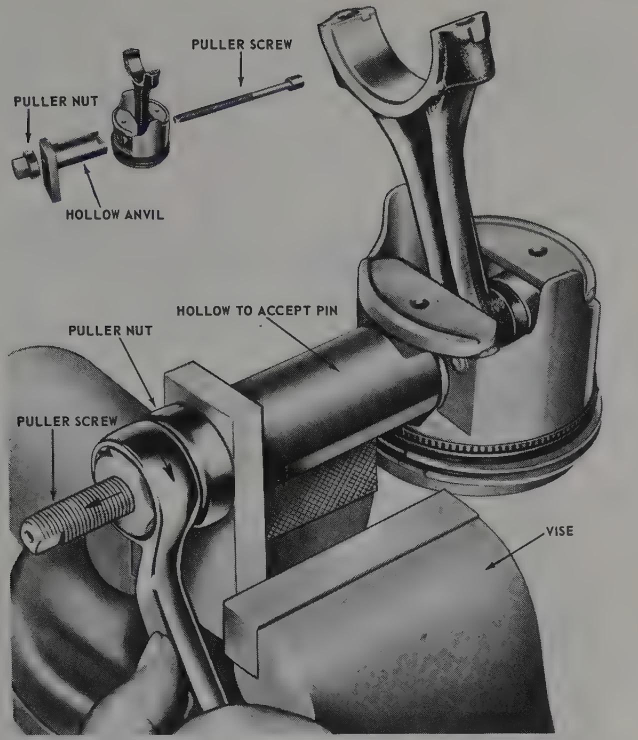


Fig. 16-46. Using a puller to remove the piston pin (pin pressed into rod). (Ford)

If pin is clamped to the rod, remove the clamp screw and tap the pin out.

FITTING PISTON PINS

Since pin-to-piston clearances are extremely small (.0002-.0005 in. or 0.005-0.0127 mm typical in aluminum pistons), proper fitting is an exacting job.

Modern honing and boring machines will do such highly accurate work that a pin will slide freely through the piston with as little as .0001 in. (0.0025 mm) clearance. Even though the pin feels free, this space would not provide sufficient oil clearance. The pin would probably seize in the piston. Fig. 16-47 shows a piston in which the pin had started to seize. Note the seizure marks in the bosses and on the pin. Seizure can literally demolish the piston.

Pin clearance in bushed rods is somewhat greater averaging around .0005 in. (0.0127 mm). In pressure fed rod bushings, the clearance is about .001 in. (0.025 mm). The pin in Fig. 16-48 had insufficient clearance and seized in the bushing. The rod oscillated around the bushing.

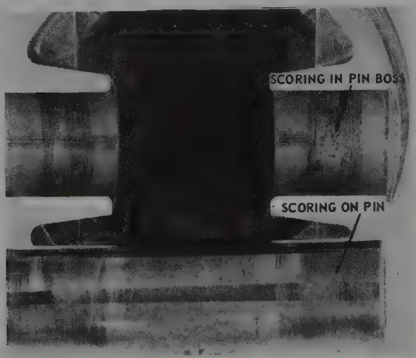


Fig. 16-47. Insufficient pin clearance caused this pin to start seizing. Note score marks.

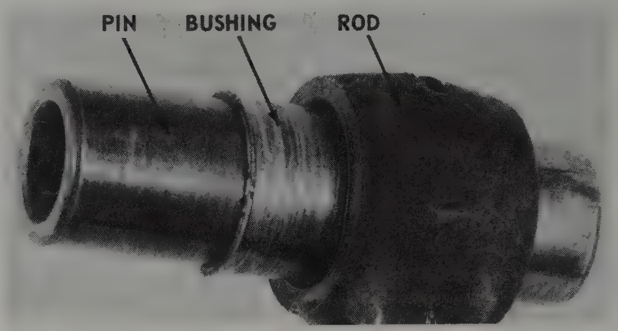


Fig. 16-48. Piston pin seized in rod bushing. Rod oscillating on bushing.

FOLLOW MANUFACTURER'S SPECIFICATIONS

Proper pin clearances depend on pin diameter, method of attachment, type of piston material, bushed or non-bushed type, and piston operating temperature. There is no ideal average that will work well on all engines. Consult and carefully follow the manufacturer's specifications.

Fig. 16-49 demonstrates the difference between a reamed finished and a honed or diamond bored finish.

DETERMINING PIN CLEARANCE

Many pin fitting machines are equipped with highly accurate measuring devices that will control pin clearance within a few ten-thousandths of an inch.

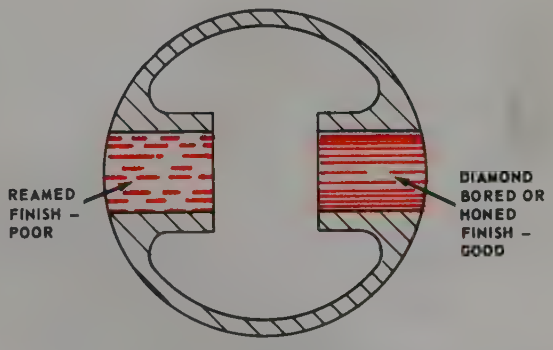


Fig. 16-49. Do not use a reamer for final fit. Such a surface will allow high initial wear. Fit pins by actual measured clearances and never by old fashioned thumb or palm push fits.

Lacking such a facility, the pin may be measured with a vernier micrometer. Bearing bore diameter should be checked with a small hole gauge and vernier micrometer. If the measurements are done carefully, accurate clearances can be determined.

BUSHING INSTALLATION AND FITTING

Bushings, although rarely used in the pistons (cast iron pistons used bushings), are still used in the upper connecting rod bore or eye where the rod is designed to oscillate on the pin.

If the bushing is in good condition but with excessive clearance, it may be honed or bored to fit an oversize pin. In cases where the bushing is beyond repair, it must be driven out and a new bushing pressed into place.

Following bushing removal, clean the rod bore and cut a SMALL chamfer on one side. Line up the oil hole and press the bushing into place. The bushing must START STRAIGHT AND REMAIN STRAIGHT UNTIL FULLY SEATED.

A press should be used to seat the bushing. Lacking a press, a vise with PARALLEL, SMOOTH jaws may be used. Avoid driving as it tends to upset (expand) the driven end and bulge the center, Fig. 16-50.

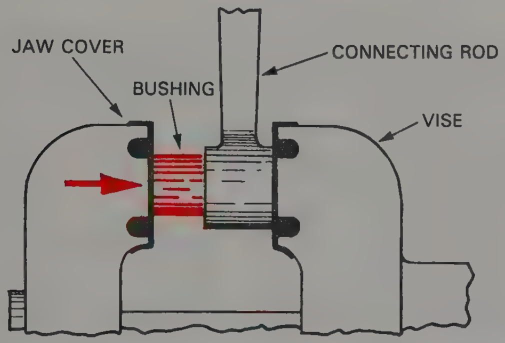


Fig. 16-50. Using a vise to seat a bushing. Note protective jaw covers.

It is advisable to burnish the bushing. This procedure expands the bushing tightly into the rod bore, preventing it from loosening and turning. Burnishing will help the bushing to conduct heat and to stand shock loads without "opening up." See Fig. 16-51.

When burnishing, support the bushing so that it is not forced from its proper location. If two bushings are used in the same bore, install one and burnish before installing the other. This will permit burnishing the last bushing without dislocation of the first.

Bore or hone the bushing to the specified clearance. Check oil hole alignment. If a great deal of bushing material must be removed, a reamer may be used to bring the bushing within a few thousands of finished size, Fig. 16-52.

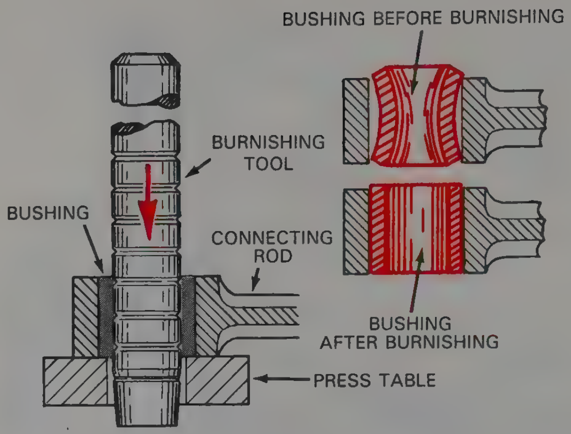


Fig. 16-51. Burnishing a bushing. Note how burnishing tool forces loose bushing tightly against the rod eye.

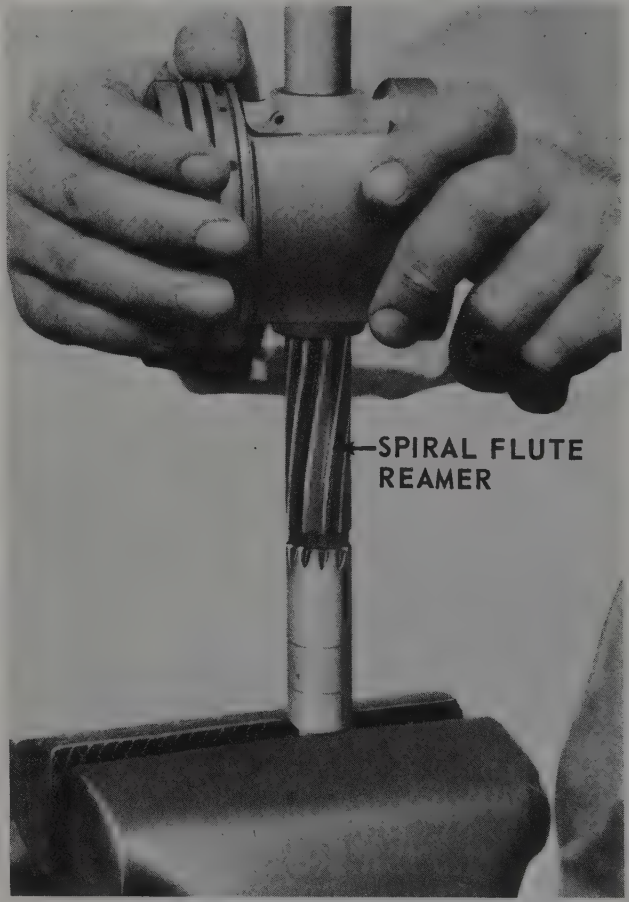


Fig. 16-52. Using a reamer to bring pin boss bores to within several thousandths of finished size. (Chevrolet)

GENERAL BORING AND HONING PRECAUTIONS

To do good work, the mechanic must thoroughly understand the boring or honing machine. A mechanic can learn how to operate it through practice on scrap rods and pistons until thoroughly competent. Despite the built-in accuracy of the machine, there is a certain feel to the operation that must be learned before first-class work can be performed. A typical honing machine is pictured in Fig. 16-53.

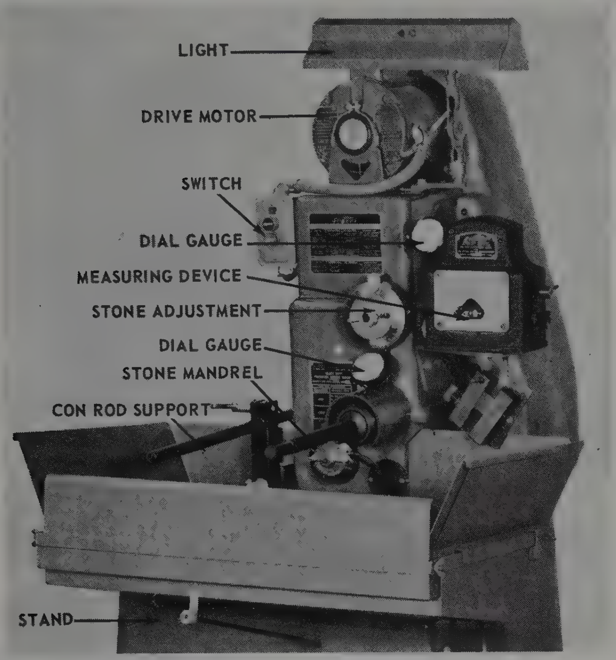

LIGHT
DRIVE MOTOR
SWITCH
DIAL GAUGE
MEASURING DEVICE
STONE ADJUSTMENT
DIAL GAUGE
STONE MANDREL
CON ROD SUPPORT
STAND

Fig. 16-53. Typical honing machine. (Sunnen)

PIN HOLE MUST BE ROUND

Honing stones loose in the bearing or looseness in a boring setup will produce oblong holes. This will provide spot contact with resultant rapid wear and failure. See Fig. 16-54.

PIN HOLES MUST BE STRAIGHT

Worn stones, not properly dressed, will produce tapered holes. Reversing the rod or piston on the hone (normally good practice) will not remove the taper but will produce a double taper. Wobbling the rod will also produce a tapered hole. See Fig. 16-55.

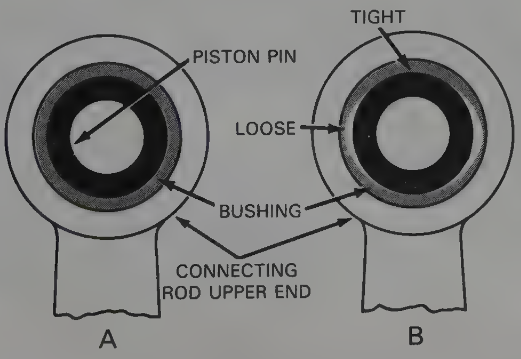

TIGHT
PISTON PIN
LOOSE
BUSHING
CONNECTING ROD UPPER END
A
B

Fig. 16-54. A—Hone bushings accurately. B—A loose honing or boring setup will produce an oblong hole.

PIN HOLES MUST BE ALIGNED

Boring or honing one pin boss and then the other, unless an accurate centering cone is used, can cause misalignment between boss pin holes. Look at Fig. 16-56.

Hole misalignment will be noticed when sliding the pin through one hole into the other. If the pin clicks or catches before entering the second hole, misalignment is present. If both boss pin holes are of the correct size, any appreciable misalignment will stop the pin from entering.

PIN HOLE MUST BE SMOOTH

Sharp cutters and properly dressed stones of correct grit size will impart an extremely smooth finish. Loose or dull cutters, rough or glazed stones will leave a rough finish that will not wear properly. See Fig. 16-57.

CLEAN PISTONS, PINS, AND RODS

Clean pistons, pins, and rods with a round bristle brush and hot, soapy water. Pay special attention to pin holes and hollow pins.

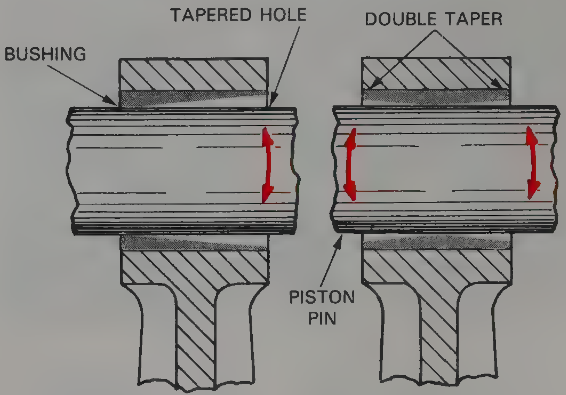

TAPERED HOLE
DOUBLE TAPER
BUSHING
PISTON PIN

Fig. 16-55. Pin holes must be straight. Tapered holes are not satisfactory.

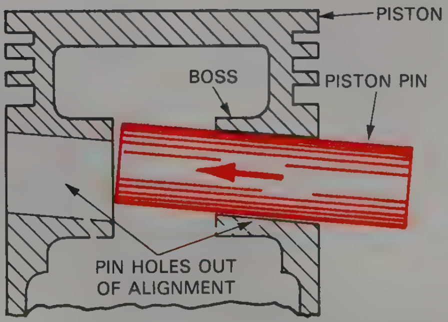

PISTON
BOSS
PISTON PIN
PIN HOLES OUT OF ALIGNMENT

Fig. 16-56. Pin holes out of alignment.

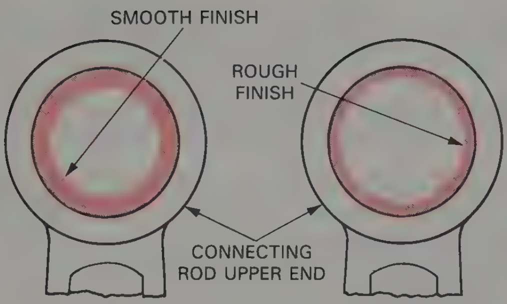

SMOOTH FINISH
ROUGH FINISH
CONNECTING ROD UPPER END

Fig. 16-57. Pin hole finish should be extremely smooth.

Fig. 16-58 shows a mechanic honing a connecting rod bushing to size. Note the support rod for the big end. Also note method of holding bushed end to prevent side pressure that would cause misalignment, bell mouthing, or taper.

Remember that pin fits must be accurate. A free pin does not always indicate adequate clearance. Clearances vary. Consult manufacturer's specifications. When a pin is fitted, keep it with the piston and rod to which it was fitted.

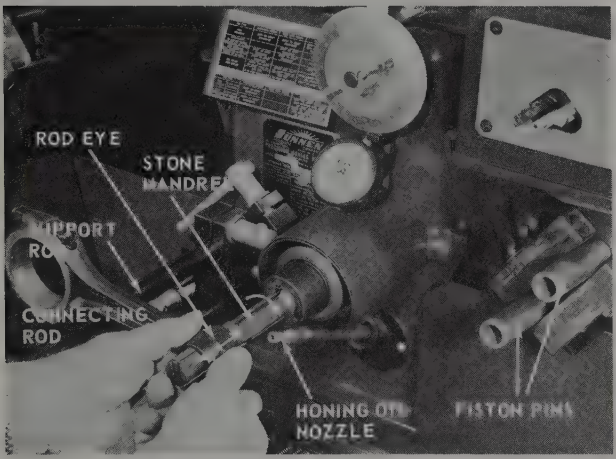

ROD EYE
STONE MANDREL
SUPPORT ROD
CONNECTING ROD
HONING OIL NOZZLE
PISTON PINS

Fig. 16-58. Honing a connecting rod bushing to size. Note how rod is held to prevent tipping. (Sunnen)

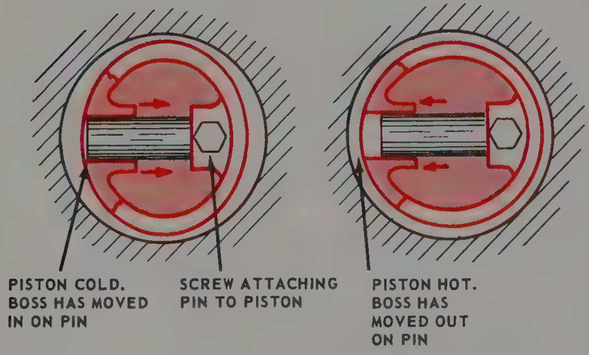

PISTON COLD. BOSS HAS MOVED IN ON PIN
SCREW ATTACHING PIN TO PISTON
PISTON HOT. BOSS HAS MOVED OUT ON PIN

Fig. 16-59. When cam ground piston is heated up, free end boss moves outward on pin.

PIN LOCKED TO PISTON—CAUTION

When fitting pins that are locked with a screw to one piston boss, do not fail to provide the specified fit on the free end. Cam ground pistons cause the bosses to travel on the pin. If one end is locked and the other is too tight, extensive piston damage may result, Fig. 16-59.

In Fig. 16-60, insufficient pin clearance in the rod ruined the piston (pin locked to one boss type).

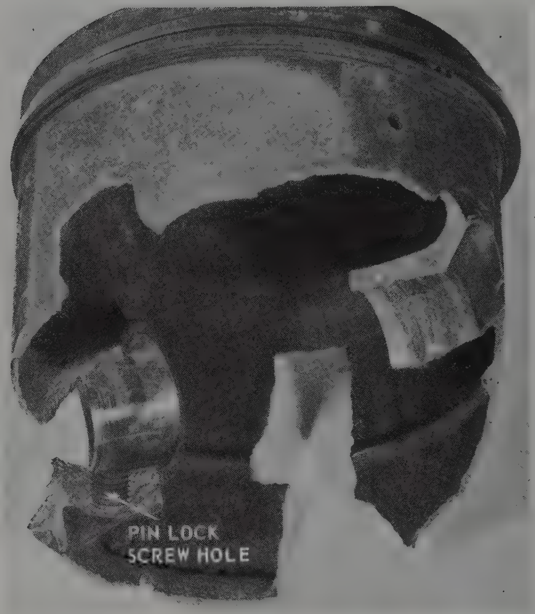

PIN LOCK SCREW HOLE

Fig. 16-60. Insufficient clearance between pin and rod caused pin to seize in rod. As pin was locked to one piston boss, something had to give—something did!

WHEN PIN IS AN INTERFERENCE (PRESS) FIT IN THE ROD

If oversize pins have been fitted to the piston, it will be necessary to hone the connecting rod to provide the specified interference fit. This fit is critical in that it must hold the pin tightly to prevent end movement that would ruin the cylinder wall.

When new pistons with standard pins are being fitted to an old rod, check to see if the rod bore has been enlarged for an oversize pin. If so, the piston must be refitted to a correct oversize pin or the rod discarded.

ASSEMBLING ROD, PISTON, AND PIN

All parts must be clean, checked for proper clearance, and thoroughly lubricated. Holding the piston and rod in the correct relationship to each other, pass the pin through the units. If an interference fit in the rod is used, a press or puller is required, Fig. 16-61.

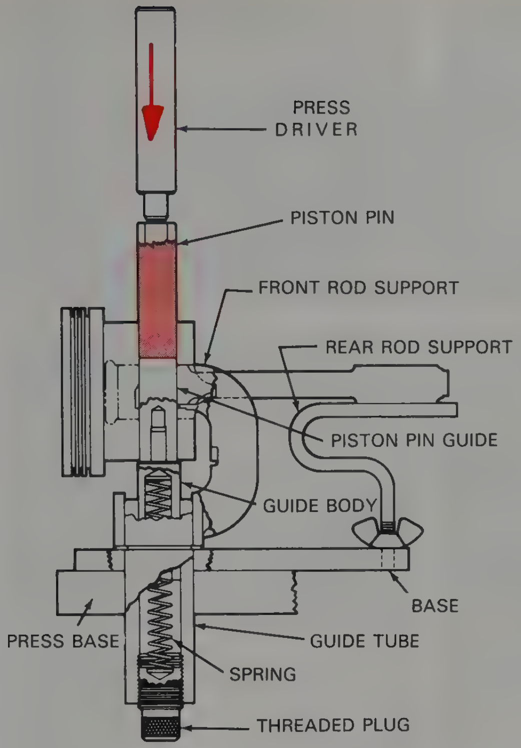

PRESS DRIVER
PISTON PIN
FRONT ROD SUPPORT
REAR ROD SUPPORT
PISTON PIN GUIDE
GUIDE BODY
BASE
PRESS BASE
GUIDE TUBE
SPRING
THREADED PLUG

Fig. 16-61. Using a press to properly install the piston pin. Pin is press fit in the connecting rod. (Chevrolet)

Some shops apply CONTROLLED heat to the rod bore to ease pin installation and prevent galling. See Fig. 16-62.

If the pin is a press fit in the rod, or is held to the rod with a clamp setup, the pin must be carefully centered so that side movement of the rod will not cause the pin to strike the cylinder wall. See Fig. 16-63.

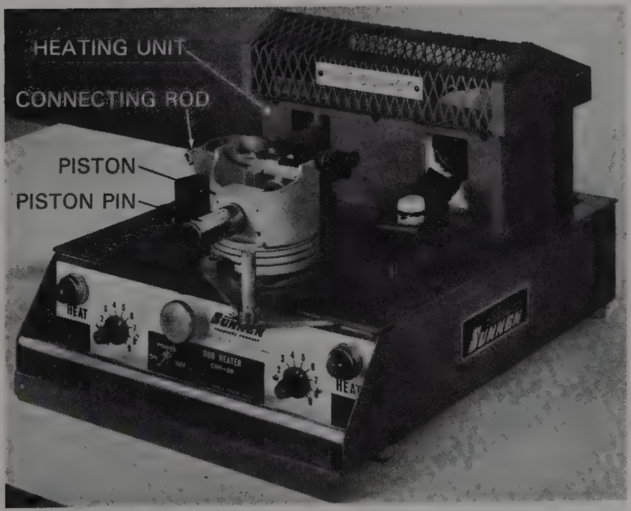

HEATING UNIT
CONNECTING ROD
PISTON
PISTON PIN

Fig. 16-62. Electric connecting rod heater. This unit has a dual heating unit for two rods. It also uses a piston vise to secure piston. Rod goes directly from heater to piston for pin installation, before much cooling of the rod takes place. (Sunnen)

TORQUE PULLER SCREW NUT

The interference fit between pin and rod can be checked by measuring the torque required to pass the pin through the rod, Fig. 16-64. Be sure to check specifications.

USE CARE WHEN INSTALLING END LOCKS

On the full floating pin installation, make certain the end locks are not distorted or weak. Check to see that they are FULLY SEATED in their grooves. In-

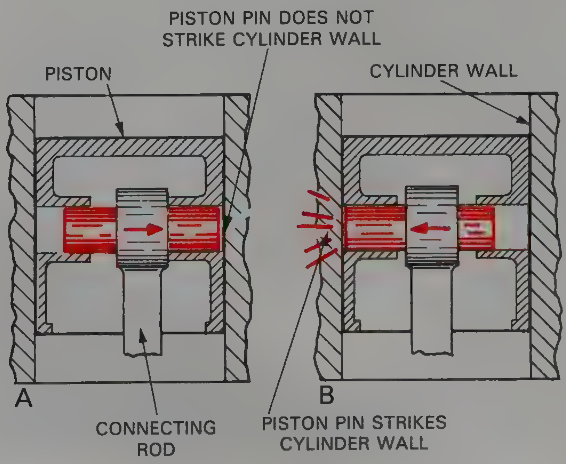

PISTON PIN DOES NOT STRIKE CYLINDER WALL
PISTON
CYLINDER WALL
A
B
CONNECTING ROD
PISTON PIN STRIKES CYLINDER WALL

Fig. 16-63. A—When the piston pin is centered in the rod, rod side movement will not cause the pin to strike the cylinder wall. B—An offset pin will cause trouble.

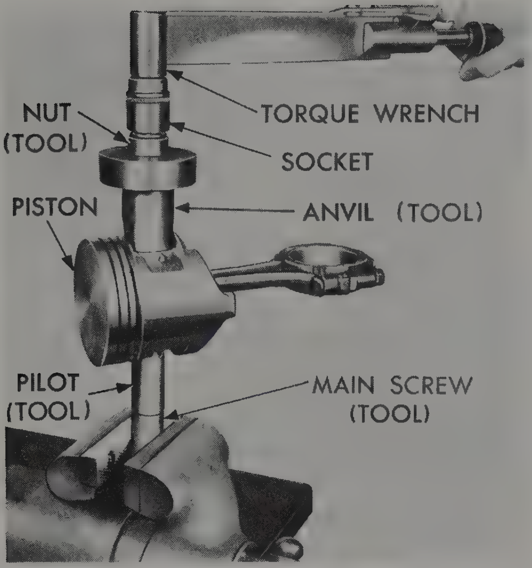


Fig. 16-64. Checking interference fit between rod and piston pin by using torque wrench. (Dodge)

stall the open end toward the bottom of the piston. This will tend to cause them to expand into the grooves during the shock period imposed during the firing stroke. Loose pin locks can actually cut through the boss from the inertia force. When removing or installing locks, spring them only as far as necessary. If the lock breaks and moves out of its groove, the cylinder, piston, or both, can be damaged. See Fig. 16-65.

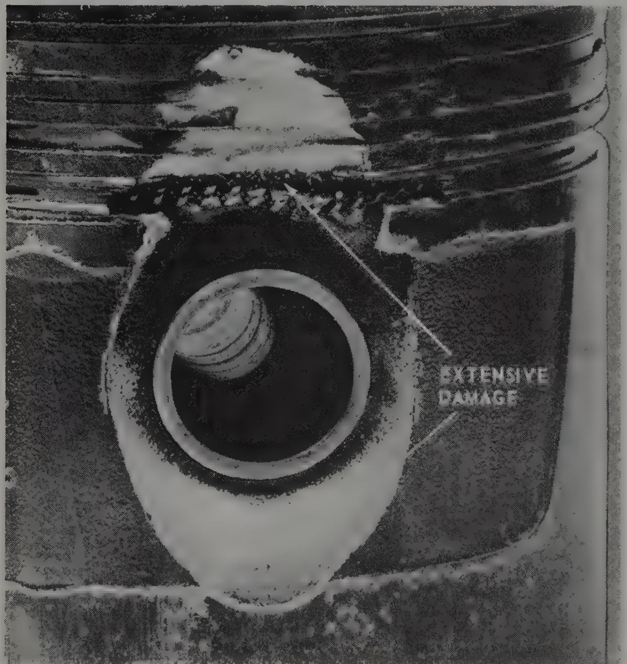


Fig. 16-65. A loose pin lock ruined this piston. Note that the pin lock area is completely gone and that damage extends through the ring area.

RING TYPES, SERVICE

The two basic ring types, COMPRESSION and OIL CONTROL, are available in a multitude of designs. The practice of chrome plating the cylinder wall contact edge of one or more rings in a set is becoming widespread. The use of chrome lengthens the service life and reduces the chance of scuffing. Special break-in coatings such as phosphate and ferrous oxide are often applied.

Compression rings are usually of the torsional twist, taper face type, or a combination of the two. Oil control rings can be of one or more piece construction using either a hump type, a circumferential coil, or a circumferential spacer-expander. See Fig. 16-66.

Rings for repair work are available in sets designed for either a rebored (no taper or out-of-roundness) or a worn cylinder. The set for installation in a rebored cylinder is commonly referred to as a factory or rebore set while the set for a worn cylinder is called engineered or oil control.

The oil control set is of a somewhat different design with stiffer expander springs to force the rings to follow the tapered walls. Mild taper (up to .005 in. or 0.13 mm) can usually be handled well by a rebore set. The more severe oil control set will produce more drag and wear. See Fig. 16-66.

RING GAP

When rings are installed in a cylinder, a certain amount of gap (clearance) must exist between the ends. As the rings heat up they expand. If the ends touch and expansion continues, scuffing, scoring, and damage will occur.

It is advisable to allow a minimum of .003 to .004 in. (0.08 to 0.10 mm) gap for each inch (25.4 mm) of cylinder diameter. For example: a 3 in. cylinder would require a gap of .009 to .012 in.

Check compression rings for proper gap, using a feeler gauge, Fig. 16-67. Start the ring by hand. Then use a piston to shove it to the bottom of the ring travel. This will square the ring with the bore.

A gap up to .008 in. per inch (0.20 mm per 25.4 mm) of bore diameter is acceptable. Anything above this would indicate a wrong size ring set.

If the gap is a few thousands small, it may be widened by clamping a small, fine tooth mill file in the vise and rubbing the ends of the ring across the file surface. Hold the ring near the ends and be very careful.

Remove the ring from the cylinder by pulling upward on the ring directly opposite the gap. If the side of the ring near the gap is lifted, the ring can be distorted or broken.

Specify cylinder diameter (standard, .010, .020, etc., oversize) when ordering ring sets.

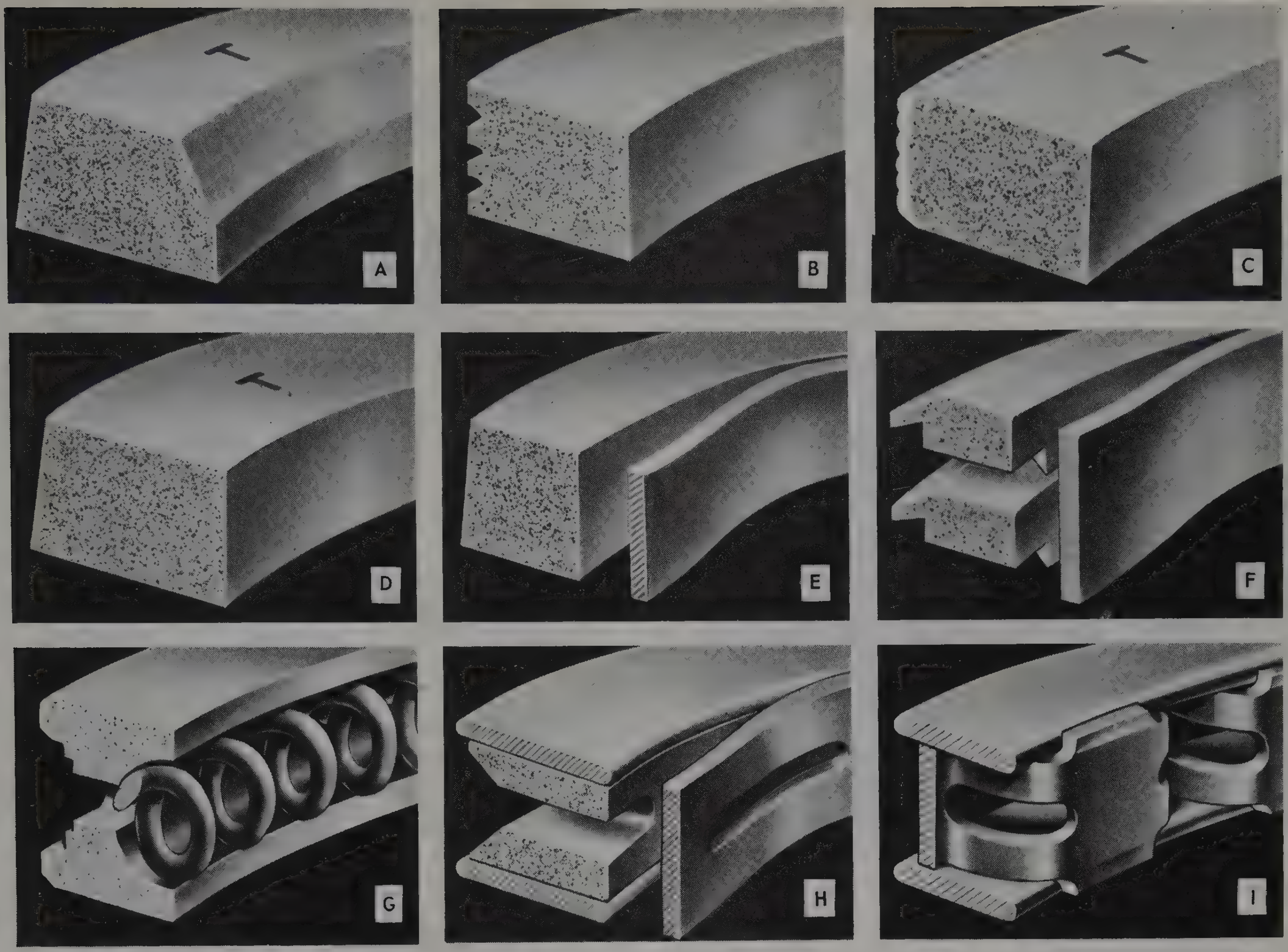


Fig. 16-66. Ring types. A—Combination torsional twist and taper face. B—Plain, grooved face. C—Plain, chrome faced. D—Taper face. E—Taper face with hump type expander. (F through I are oil rings) F—Twin scraper, hump type expander. G—Chromed twin scraper with circumferential coil expander. H—Cast iron spacer, two chrome side rails, hump expander. I—Two chrome side rails, circumferential expander-spacer. (Sealed Power)

PISTON RING GROOVE DEPTH

Rings are made for a variety of groove depths. The ring must not touch the bottom of the groove when installed in the cylinder. The groove, however, should not be too deep because certain types of expanders push outward from the groove bottom. Excessive groove depth will reduce expander pressure.

A gauge, as shown in Fig. 16-68, may be used to check the oil ring groove depth.

Shallow grooves, if correct rings are not available,

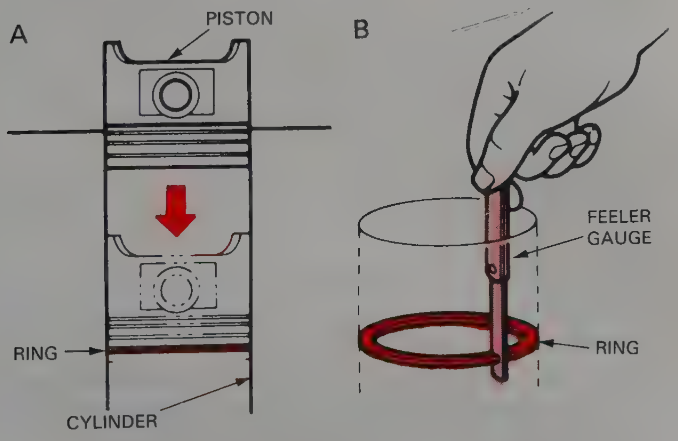

A
PISTON
RING
CYLINDER
B
FEELER
GAUGE
RING

Fig. 16-67. To measure ring gap: A—Use piston to seat ring squarely at bottom of ring travel in cylinder. B—Measure ring gap with feeler gauge. (Mazda)

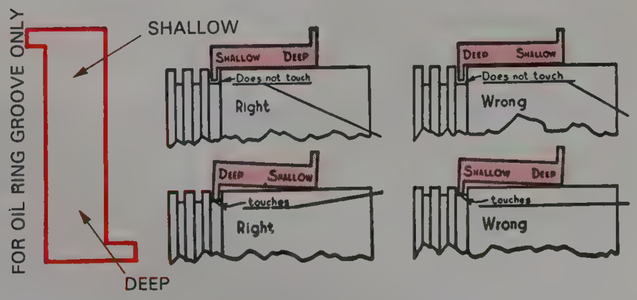

FOR OIL RING GROOVE ONLY
SHALLOW
DEEP
SHALLOW DEEP
Does not touch
Right
DEEP SHALLOW
Does not touch
Wrong
DEEP SHALLOW
touches
Right
SHALLOW DEEP
touches
Wrong

Fig. 16-68. When a gauge such as this is enclosed with ring set, be sure to use it. The shallow tip SHOULD NOT TOUCH. The deep tip SHOULD TOUCH. If the deep does not touch or if shallow does, ring set is wrong for piston in question. (Hastings)

can be deepened in some cases. Some manufacturers supply shims to reduce excessive depth.

RING SIDE CLEARANCE

Rings should be rolled around in their respective grooves to check for binding. See Fig. 16-69.

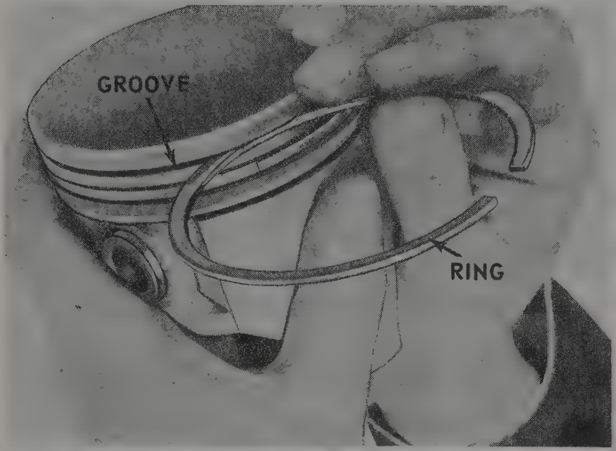


Fig. 16-69. Roll the ring completely around groove to check for binding.

Check ring side clearance by inserting the ring into the groove and passing a feeler gauge between the ring and groove side. Check in several spots around the groove. Clearance should not exceed .006 in. (0.15 mm) nor be less than .0015 in. (0.038 mm) for top rings. (For procedure used for groove reconditioning, see material in this chapter on piston service.) See Fig. 16-70.

Some multiple piece oil rings are designed so that the expander-spacer forces the rails not only against the cylinder walls but against the ring groove sides as well. This type obviously has NO side clearance.

INSTALLING RINGS

Grasp the connecting rod in a CLEAN vise. All ring grooves must be clean. Make certain oil ring groove drain holes are open.

Starting with the bottom oil ring, install according to directions supplied with rings. Multiple piece oil ring side rails must be spiraled over the piston (do not try to expand them). This is shown in Fig. 16-71.

Note that the ends of the flexible spacer in A, Fig. 16-71, MUST BE BUTTED TOGETHER. DO NOT LET THEM OVERLAP. BUTTED ENDS MUST BE LOCATED OVER A SOLID PORTION OF THE GROOVE BOTTOM. Some grooves have little solid area. Special shims are available to prevent the spacer ends from bending inward through the groove.

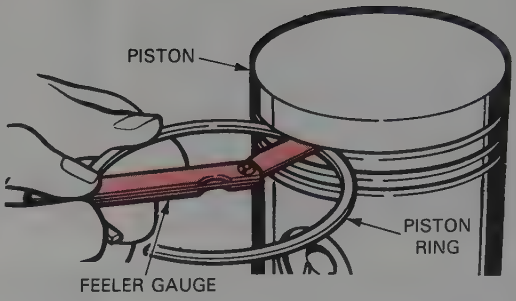
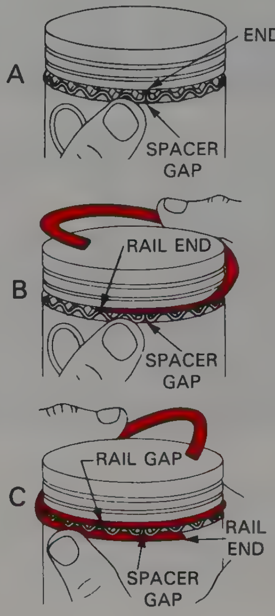


Fig. 16-70. Using a feeler gauge to check ring side clearance in its groove. (Case)



PLACE SPACER IN GROOVE WITH ENDS OVER SOLID PORTION OF GROOVE BOTTOM.

WITH THUMB HOLDING SPACER ENDS, SPIRAL STEEL RAIL INTO GROOVE ABOVE SPACER. LOCATE RAIL GAP APPROXIMATELY 1 IN. (25.4 mm) TO LEFT OF SPACER ENDS.

SPIRAL REMAINING RAIL INTO GROOVE BELOW SPACER. LOCATE RAIL GAP APPROXIMATELY 1 IN. (25.4 mm) TO RIGHT OF SPACER ENDS.

Fig. 16-71. Oil ring side rails must be spiraled into place. Do not cut off ends of expander spacer.

After both rails are installed, CHECK THE SPACER ENDS TO MAKE SURE THEY ARE NOT OVERLAPPED.

When spiraling rails into position, be careful to avoid scoring the piston with the sharp rail end. The end can be slid over a piece of stiff feeler stock to prevent piston damage.

Use a good quality ring expander to install the remaining rings. Do not expand any ring more than necessary. See Fig. 16-72.

Be careful to install the rings with the side up as recommended. Many rings are marked "TOP." This obviously faces the top of the piston.

If no markings are present and no illustrations are provided, a study of the ring profile will usually determine the top side. Study the typical ring profiles in Fig. 16-73.

Do not forget to install expanders for compression rings when so equipped.

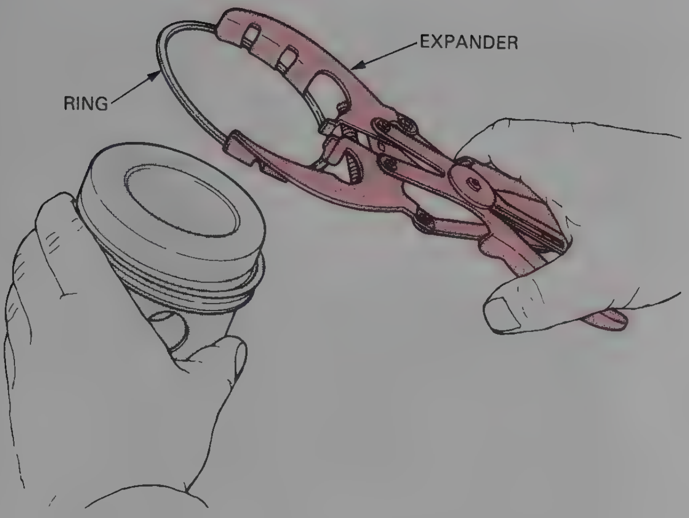


Fig. 16-72. Use a good ring expander to install rings. (Perfect Circle)

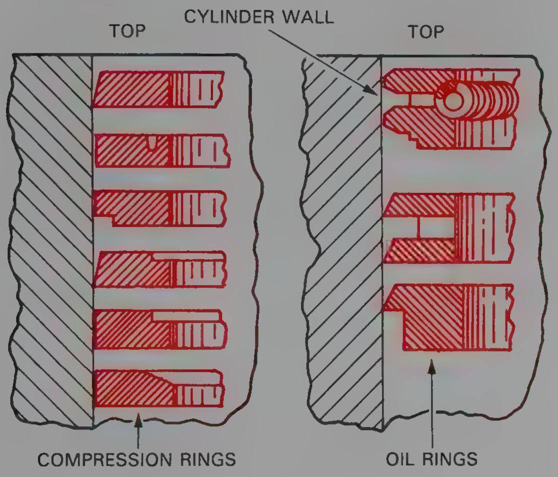


Fig. 16-73. Rings of this general shape are usually installed as shown.

RING GAP SPACING

On multiple piece rings, follow manufacturer's recommendations. Although rings tend to float (move around in grooves), it is a good idea to space the ring gaps around the piston so that they are not in alignment.

CONNECTING ROD SERVICE

Before removing any rods, check to see that all rods are marked and that both upper and lower bearing halves are marked with the same number. They should be marked in order starting with the number one cylinder. Note the relationship between the numbers and the block so the rods can be installed without reversing. If the rods are not numbered or if one or more rods show the wrong number, renumber them in the proper order. See Fig. 16-74.

CORRECT NUMBERING OF ALL RODS IS IMPORTANT. THE ROD AND PISTON MUST BE IN THE CORRECT RELATIONSHIP TO EACH OTHER, REPLACED IN THE PROPER CYLINDER, AND WITH THE MARKS FACING IN THE ORIGINAL DIRECTION.

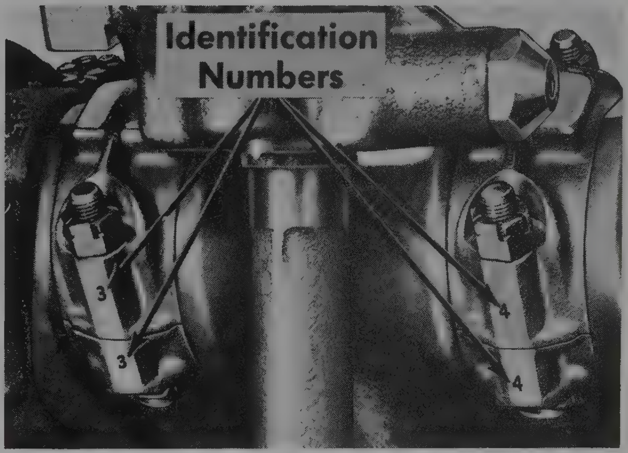


Fig. 16-74. Check connecting rods for correct identification numbering. (G.M.C.)

CONNECTING ROD REMOVAL

Rotate the crankshaft to bring the rod journal near bottom dead center (BDC). Remove the rod cap. If working on an older model car in which shims are used, remove the shims and mark position on the rod. Install protectors over the rod bolts to prevent nicking the journal. If using a driving and installing tool as shown in Fig. 16-75, drive the rod and piston up out of the cylinder. If no driver is used, a clean hammer handle can be used to tap the rod.

CAUTION: THE RING RIDGE MUST BE REMOVED BEFORE PULLING PISTONS. THIS WILL PREVENT THE PISTON RINGS FROM CATCHING ON THE RIDGE AND POSSIBLY BREAKING THE PISTON LANDS.

CONNECTING RODS MAY NEED RECONDITIONING

When rods must be removed for ring work, they too usually need reconditioning. The modern high rpm, high horsepower engine imposes tremendous loads on the rods. In order to reduce reciprocating weight, the rods are made as light as feasible. This lightness, while beneficial, does tend to allow distortion of the big end bearing bore. It can also allow the rod to twist and bend. High rpm, heavy loads, centrifugal and inertia

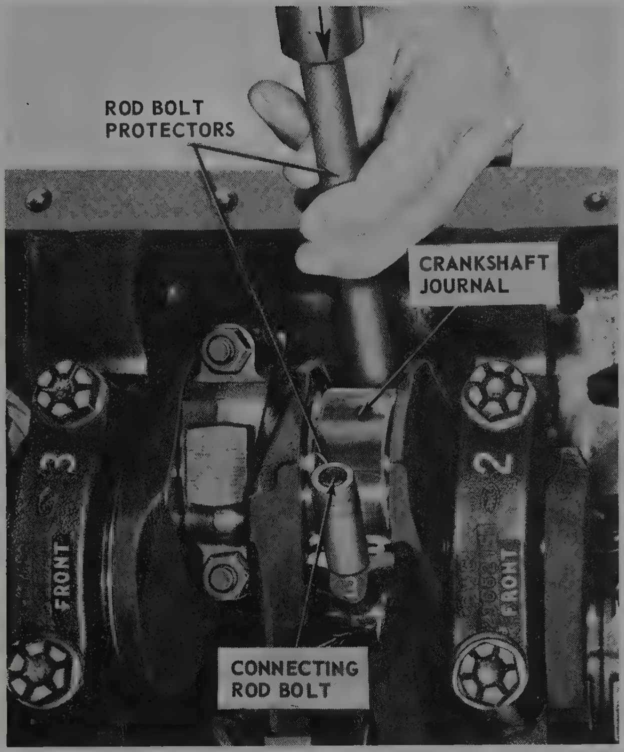


Fig. 16-75. Driving against rod bolt protector to remove piston and rod assembly.

forces coupled with the effects of heating and cooling are primarily responsible.

CONNECTING RODS SHOULD ALWAYS BE CHECKED FOR TWIST, BEND, AND BEARING BORE DISTORTION (OUT-OF-ROUNDNESS).

CONNECTING ROD TWIST AND BEND

Rods can have either twist or bend or both. Twisting is a condition in which the centerlines of the upper and lower rod bearing bores are out of alignment in a horizontal plane. Bend is when the centerlines are misaligned in a vertical direction. See Fig. 16-76.

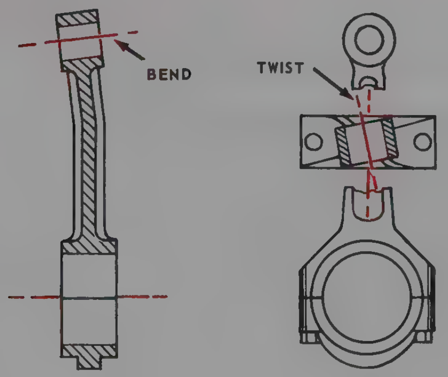


Fig. 16-76. Bend and twist or a combination of both can be present in a connecting rod.

Note the wear pattern on the piston in Fig. 16-77. The top, right side of the piston is worn. A diagonal wear pattern extends down to the lower left portion of the skirt. This wear is caused by a misaligned rod.

Fig. 16-78 shows some wear spots caused by a bent connecting rod.

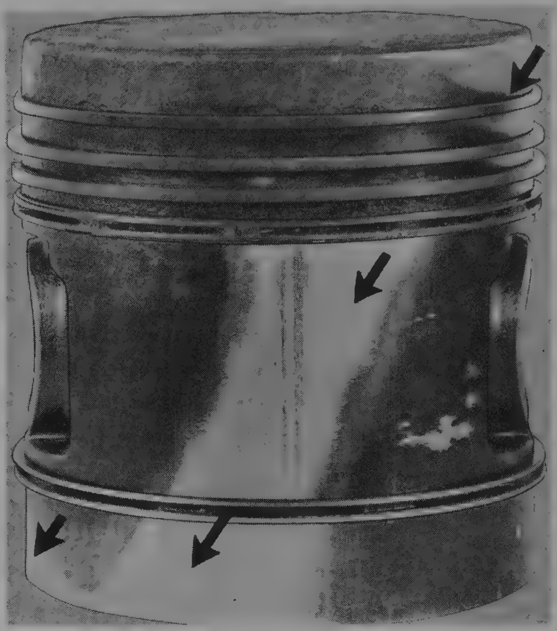


Fig. 16-77. Piston wear pattern caused by misaligned rod.

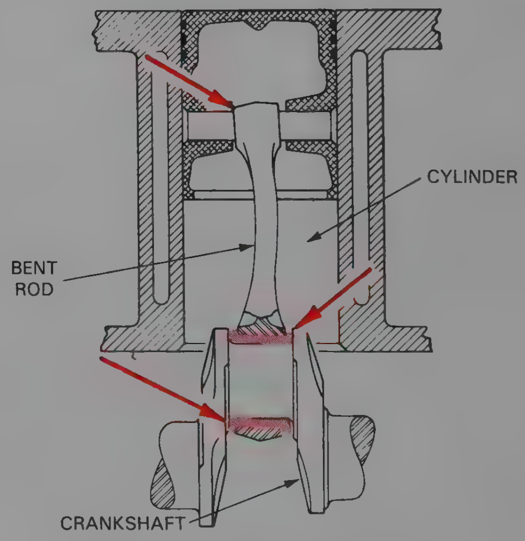


Fig. 16-78. Bent connecting rod wear points. Also note piston wear pattern in Fig. 16-77. (Federal-Mogul)

CHECKING FOR ROD TWIST AND BEND

There are a number of rod alignment tools available. All have one thing in common—they must be used with skill and care.

Two such tools are shown in Figs. 16-79 and 16-80. Note that the piston pin rests on two thin steel V's. To use it, basically, the two V's are spaced correctly. The piston pin is held securely to the V's. The test rod blades and lower bearing bore are brought together in two positions. When the top test rod is raised against the top of the bearing bore, the indicator needle shows the amount of BEND. Bringing the side test rod blade against the side of the bearing bore, just above the parting line, shows the amount of TWIST. See Figs. 16-79 and 16-80.

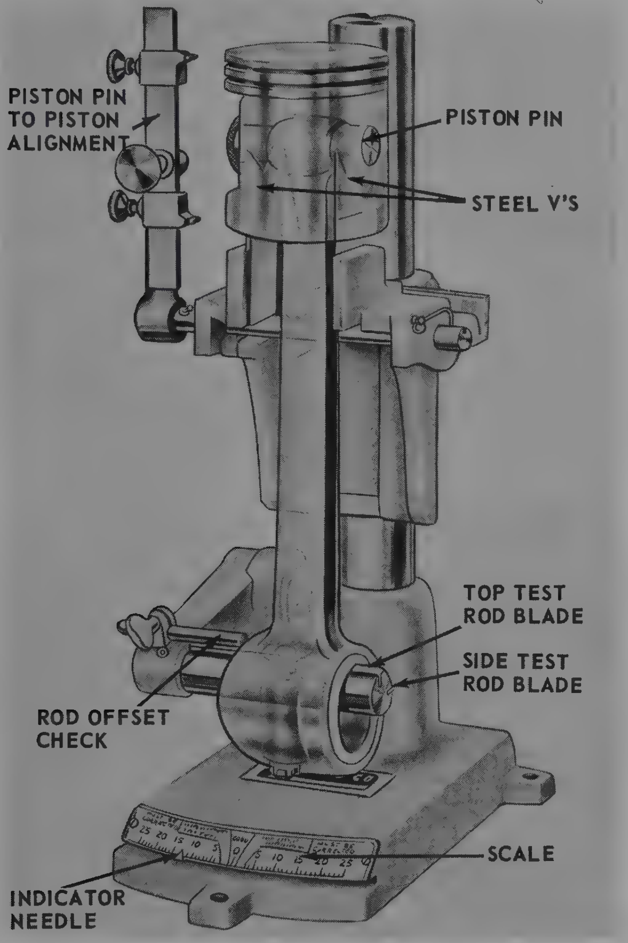


Fig. 16-79. One type of rod aligner.

REMOVING BEND OR TWIST

Removing bend or twist is a simple operation, yet it requires care. One method employs a hand bending bar. The big end bearing is clamped in a smooth vise, the bar is inserted into the hollow piston pin and lifted or lowered (to correct bend) or pulled sideways (to correct twist). By using anvils in different positions in a hydraulic rod straightening press, Fig. 16-81, both bend and twist can be removed. NOTE: Some car makers recommend scrapping bent or twisted rods.

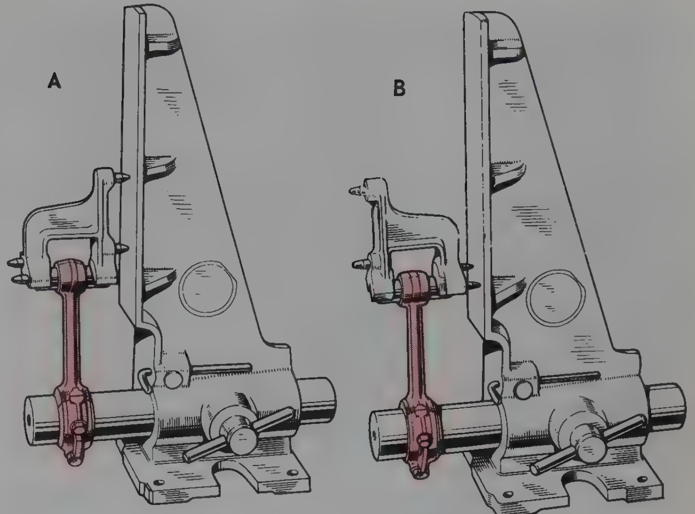


Fig. 16-80. Tool for checking connecting rod. A—Checking rod bend. B—Checking rod twist.

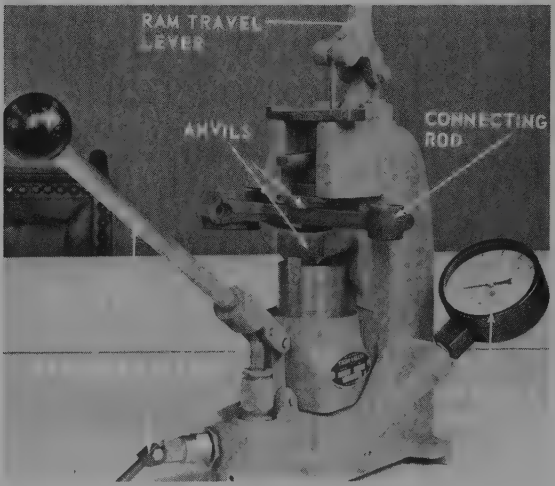


Fig. 16-81. Hydraulic connecting rod straightener. (Storm-Vulcan)

AVOID BENDING OFFSET

When trying to straighten a bent rod, it is possible to offset the rod (move upper bearing bore to one side in relation to lower bore). This is caused by bending an area other than that causing the original bend. See Fig. 16-82.

Do not confuse this condition with a regular offset connecting rod. Rods are occasionally offset to provide proper alignment between cylinder and crank journal.

Some offset rods are pictured in Fig. 16-83. Notice how the web centerline (C/L) intersects the lower bore to one side. Also note how the offset on each rod faces different sides.

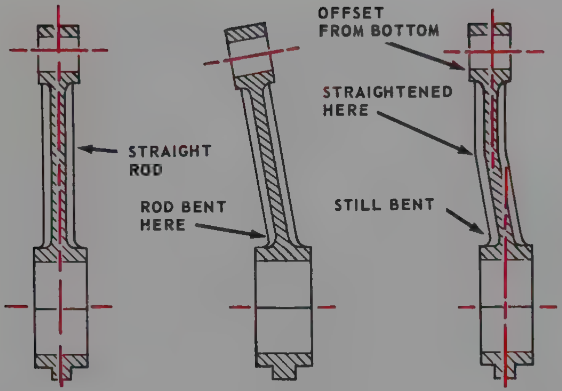


Fig. 16-82. A rod can be accidentally offset by straightening in an area other than that bent.

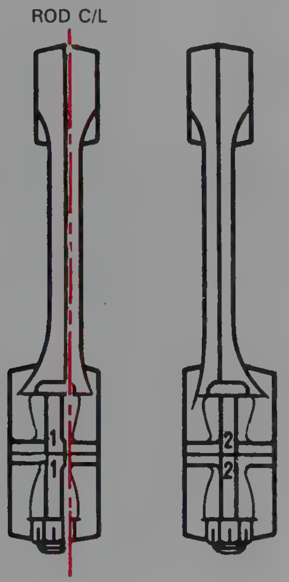


Fig. 16-83. A pair of regular offset connecting rods. Note numbering on rods. (Fiat)

CONNECTING ROD PISTON PIN BORE

Checking and reconditioning the upper connecting rod bore and bushings (where used) is covered in this chapter in the section on piston and piston pin service.

CHECKING CONNECTING ROD BIG END BORE

The connecting rod big end bearing bore should be checked for ROUNDNESS, BORE SIZE, STRAIGHTNESS, AND SURFACE CONDITION. Refer to Fig. 16-84.

BORE ROUNDNESS

After the cap is aligned and torqued to the rod, the connecting rod big end bore should be checked for out-of-roundness by either measuring with a telescoping gauge and micrometer, or by using an out-of-roundness gauge as shown in Fig. 16-85. Out-of-roundness should not exceed .001 in. (0.025 mm). If the crankpin journal is at maximum out-of-round limits, the bore out-of-roundness should be even less than .001 in. (0.025 mm).

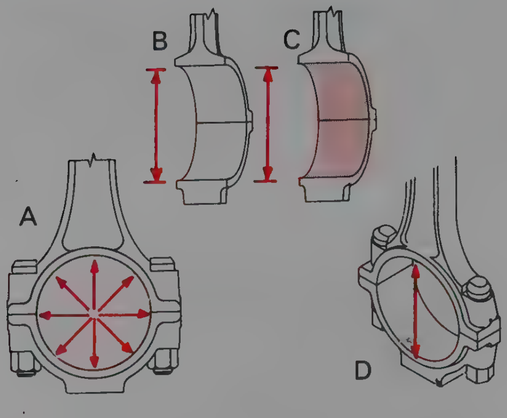


Fig. 16-84. Important connecting rod big end bore checks. A—Out-of-roundness. B—Straightness. C—Surface condition. D—Bore size.

The rod bore should be checked in several positions to give an accurate reading, Fig. 16-86.

As a general rule, bore elongation direction will vary from a vertical to around 30 deg. from vertical. See Fig. 16-87.

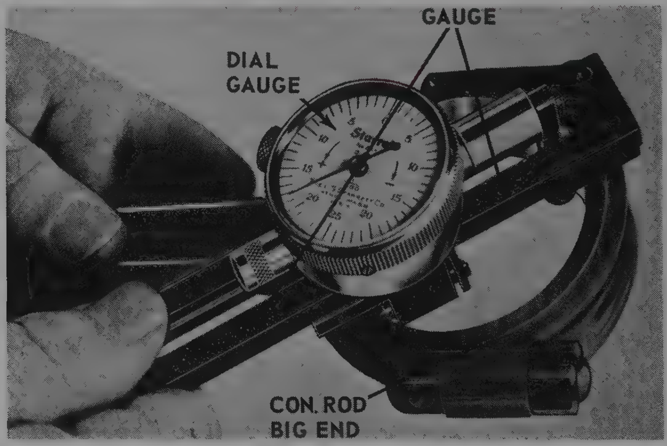


Fig. 16-85. Connecting rod big end bore out-of-roundness can be quickly determined with this type gauge. (Clevite)

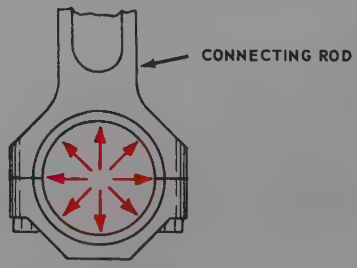


Fig. 16-86. Measure bore in directions shown by arrows in color to determine out-of-roundness.

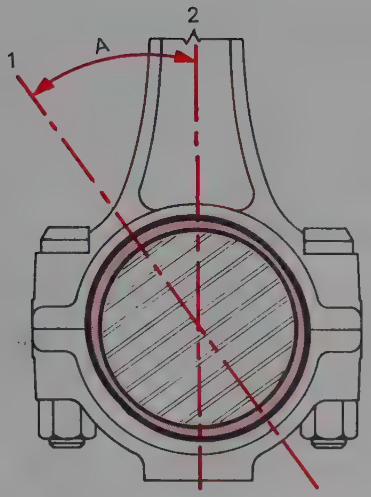


Fig. 16-87. Connecting rod bore elongations will generally be in area A between centerlines 1 and 2.

CORRECTING BORE OUT-OF-ROUNDNESS—STOCK REMOVAL

After determining the amount of out-of-roundness, half of the amount of material required for correction is removed from the upper bore and half from the lower bore half. The special grinder in Fig. 16-88 is removing a specific amount from the upper bore parting surfaces.

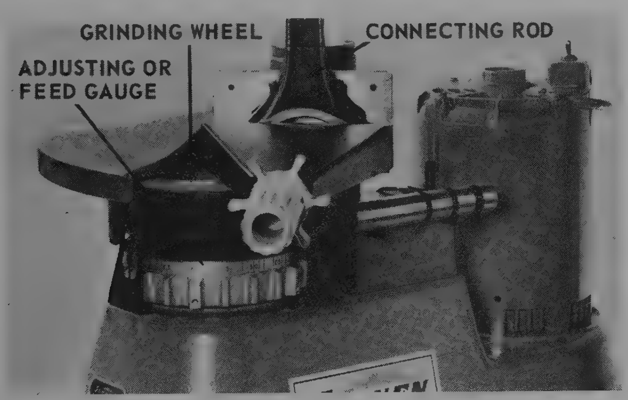


Fig. 16-88. Removing stock from connecting rod bore upper parting surface. An equal amount will then be removed from cap. (Sunnen)

Following stock removal, the cap is assembled to the rod and properly torqued. Note the jig in Fig. 16-89 that holds both upper and lower bore halves in alignment. This also removes any twisting strain applied by torquing.

RESIZE BORE

The rod bores, Fig. 16-90, are being honed to size. Note the support arms. When honing, direct a stream of honing oil so that an ample amount will enter. Move the rods back and forth over the stones, being careful to avoid exerting any side pressure that would cause the rods to tip. Keep the stones snug in the bores to reduce chatter. The stones must be of the correct grit size (to produce a 30-40 micro inch finish) and should be kept dressed to insure straight, smooth bores.

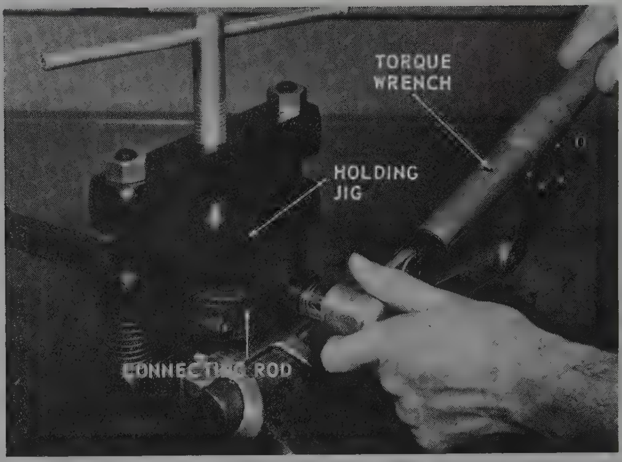


Fig. 16-89. Holding jig aligns connecting rod bore halves and relieves rod of torquing strain.

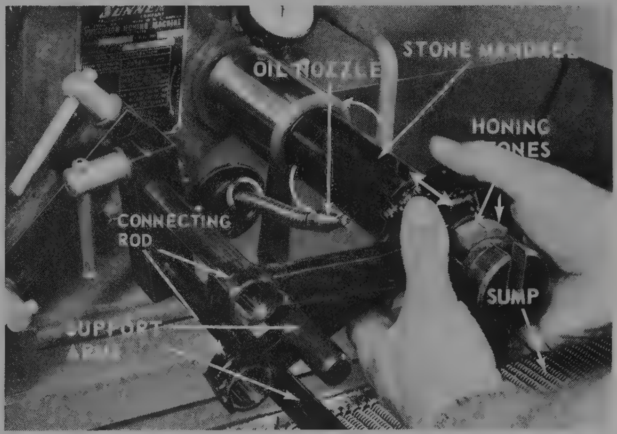


Fig. 16-90. Honing the connecting rod big end bores back to factory specifications.

CHECK BORE SIZE OFTEN

After the initial removal of rough stock with the hone, check the bore size often to avoid honing oversize. Fig. 16-91 illustrates the use of a special precision gauge to determine bore diameter.

With careful work, it will be possible to bring the bore back to the original size and limit out-of-roundness to the generally recommended .0003 in. (0.0076 mm).

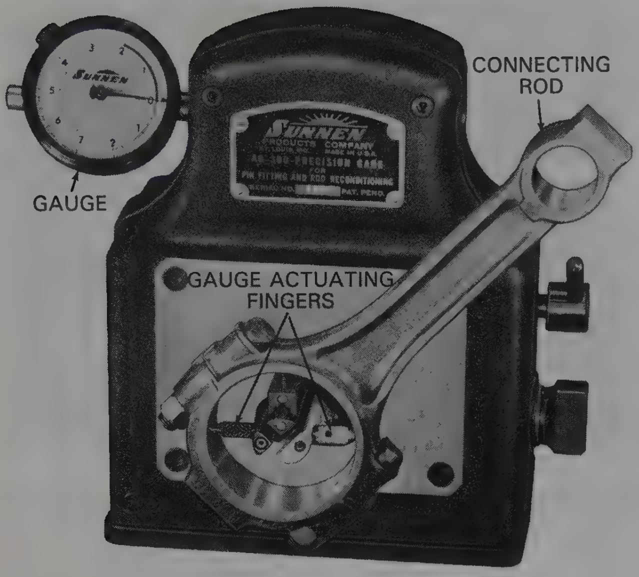


Fig. 16-91. One type of precision gauge used to check connecting rod bore for out-of-roundness and to determine pin fit. (Sunnen)

FOUR BASIC STEPS

The four basic steps involved in big end bore reconditioning are pictured in Fig. 16-92:

A. Assembled, torqued, and rod diameter checked. Note out-of-roundness (amount E-E).
B. Stock ground from parting surfaces S-S.
C. Rod cap reassembled and torqued. Vertical bore diameter now smaller than original diameter (amount G-G).
D. Bore honed to original size. Out-of-roundness has now been removed.

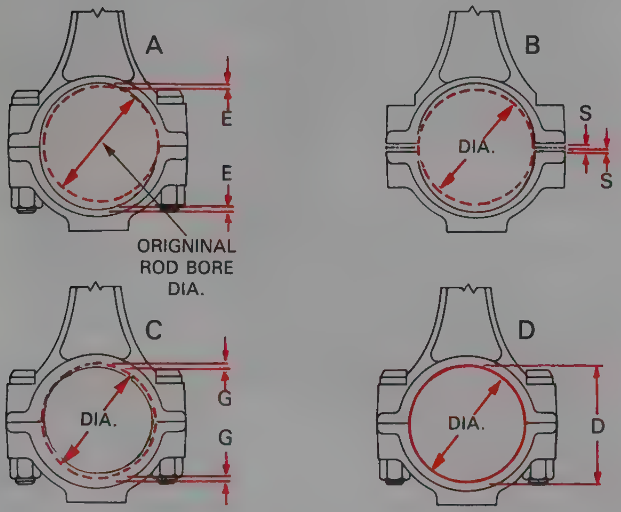


Fig. 16-92. Four steps in connecting rod big end bore reconditioning. A—Check bore. B—Remove stock from parting surfaces. C—Assemble and torque. D—Hone to size.

CHECK FOR BEND AND TWIST FOLLOWING BORE RESIZING

The rod should always be carefully checked for bend and twist after reconditioning either the wrist pin or big end bore.

WASH THOROUGHLY

Use plenty of hot, soapy water followed by a hot water rinse to completely clean the rod. Pay attention to locking lip recesses, bolt holes, and other areas where grit may be trapped.

CAUTION—When torquing caps (out of engine), pressing piston pins into the rod upper bore or, grasping rods in a vise, use extreme care to avoid bending or twisting the rods.

INSTALLING ROD AND PISTON ASSEMBLY

Give the rod and piston assembly a final check to make certain the piston pin is centered and secure. Check that the piston and rod are correctly assembled in relation to each other. Check that the rings are properly installed and that spit holes, where used, are open. See Fig. 16-93.

LUBRICATE

Squirt a heavy coat of clean engine oil (20W) over the rings and piston. Apply plenty to the pin and work the rod back and forth to insure oil enters the pin bushing. Hands and work area must be CLEAN. See Fig. 16-94.

USE RING COMPRESSOR

Grasp the rod in a vise. Slide a CLEAN ring compressor down over the rings until the lower tightening band is below the lowest ring. Tighten the compressor securely. TAP LIGHTLY AROUND THE OUTSIDE OF THE COMPRESSOR USING THE TIGHTENING WRENCH. THEN, RETIGHTENING. THIS WILL INSURE THE RINGS ARE FULLY COMPRESSED.

Snap in the upper rod bearing insert and lubricate. Install the journal protectors. Turn the crankshaft so that the journal concerned is at bottom dead center. Slide the exposed piston skirt into the cylinder keeping the rod aligned with the journal. Make certain the piston identification marks face the correct direction.

Using a hammer handle, tap the piston through the compressor and into the cylinder. The piston should enter with light tapping. If the piston catches on the way in, a ring is probably hung up on the cylinder block surface. DO NOT FORCE THE PISTON IN. REMOVE AND REINSTALL THE COMPRESSOR.

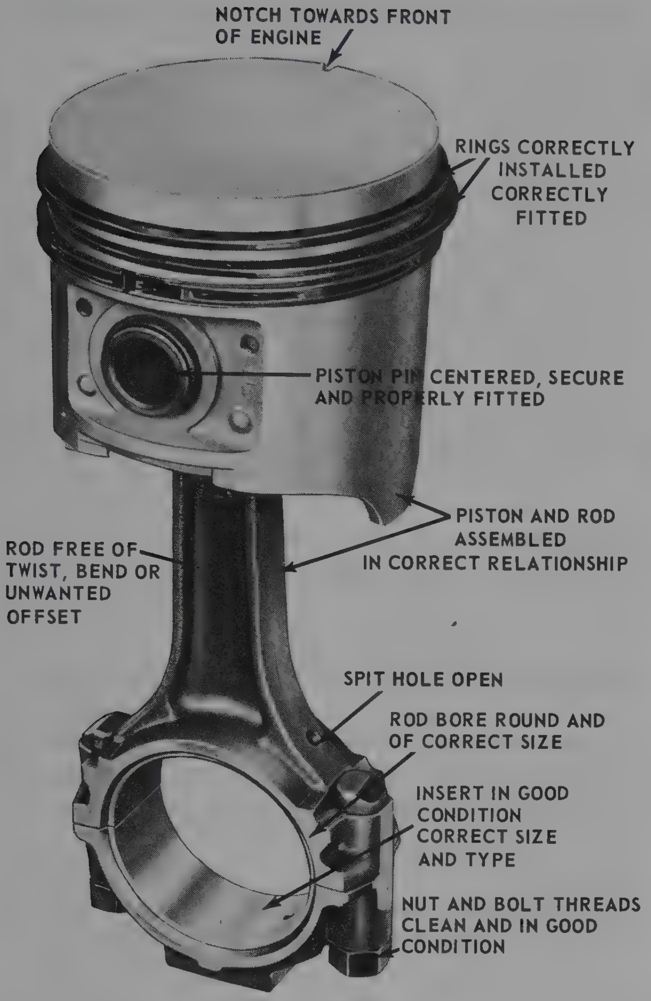

NOTCH TOWARDS FRONT OF ENGINE
RINGS CORRECTLY INSTALLED CORRECTLY FITTED
PISTON PIN CENTERED, SECURE AND PROPERLY FITTED
PISTON AND ROD ASSEMBLED IN CORRECT RELATIONSHIP
ROD FREE OF TWIST, BEND OR UNWANTED OFFSET
SPIT HOLE OPEN
ROD BORE ROUND AND OF CORRECT SIZE
INSERT IN GOOD CONDITION CORRECT SIZE AND TYPE
NUT AND BOLT THREADS CLEAN AND IN GOOD CONDITION

Fig. 16-93. Give rod and piston assembly a final check before installing in engine. (Plymouth)

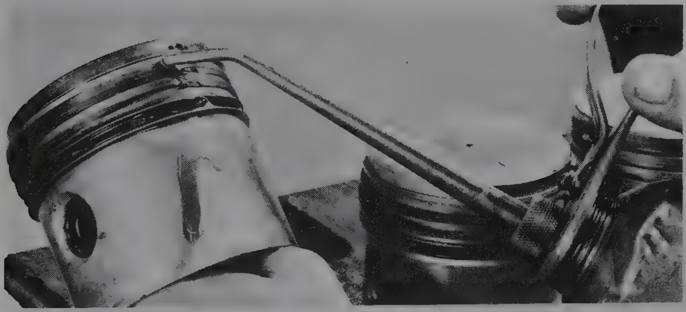


Fig. 16-94. Cylinder, piston, rings, pin, and rod bearings must be heavily oiled. (Perfect Circle)

While tapping the piston into the cylinder, it is important to keep the compressor firmly against the block. Failure to do this may allow it to ride up far enough for an oil ring side rail to pop out and hang up. See Fig. 16-95.

A slightly different shaped compressor is required for blocks with slanted top surface, Fig. 16-96.

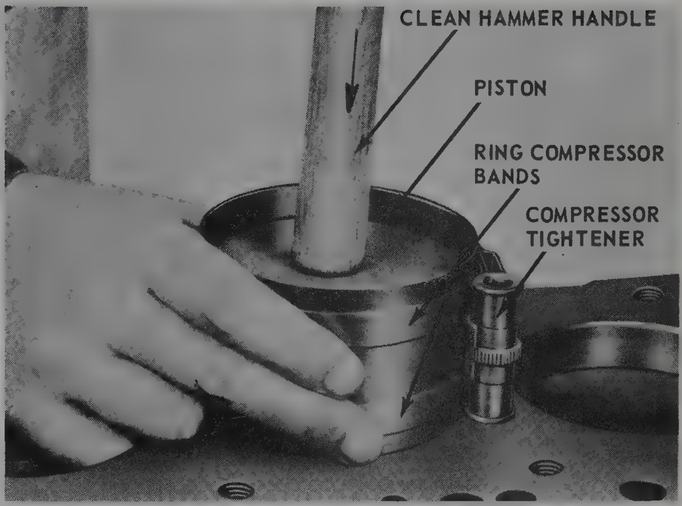

CLEAN HAMMER HANDLE
PISTON
RING COMPRESSOR BANDS
COMPRESSOR TIGHTENER

Fig. 16-95. Properly adjusted ring compressor makes piston installation easy. Hold compressor tightly against block surface. (G.M.C.)

Guide the rod bearing around the journal as the piston is either tapped or pulled down through the cylinder. Journal protectors such as those in Fig. 16-97 provide a handle that is very handy to pull the rod into position on the journal.

Snap in the lower bearing insert. Lubricate and install the cap so that the cap number is on the same side as the upper mark. Run the cap bolts or nuts up until the cap is snug.

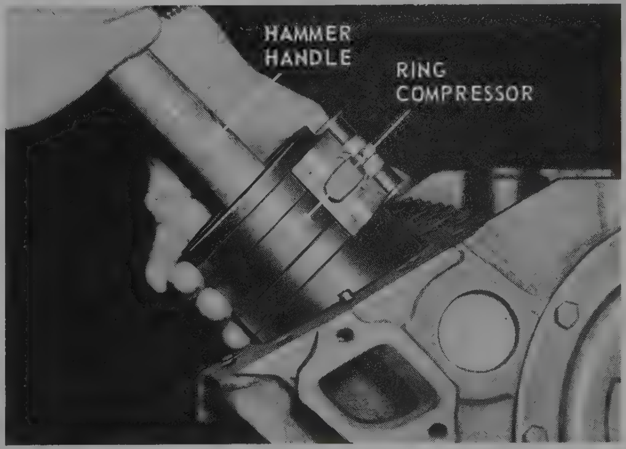

HAMMER HANDLE
RING COMPRESSOR

Fig. 16-96. Slanted block surface requires a slightly different shaped ring compressor. (Chevrolet)

If the journal serves a single rod, turn the crankshaft a couple of revolutions to allow the rod to center before the final bearing tightening. If two rods operate on the same journal, install both rods and then revolve the shaft.

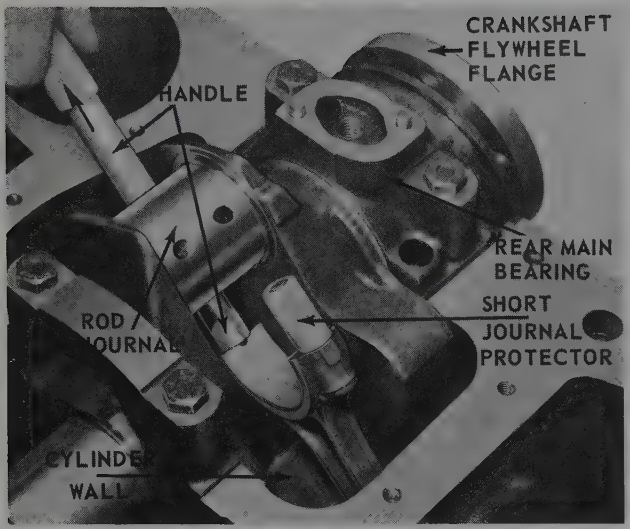

CRANKSHAFT FLYWHEEL FLANGE
HANDLE
REAR MAIN BEARING
ROD / JOURNAL
SHORT JOURNAL PROTECTOR
CYLINDER WALL

Fig. 16-97. Pulling the rod into contact with the crankshaft journal.

CHECKING CONNECTING ROD BEARING CLEARANCE

Rotate the crankshaft to BDC (when journal is ROUND). If the journal is out-of-round, rotate downward just far enough to remove the cap. This will allow a check more in line with the widest journal diameter. Remove the cap. Wipe oil from journal and insert. Place Plastigage across insert about 1/4 in. (6.35 mm) off center. See Fig. 16-98. Install cap and torque. It is important to make certain the upper rod bearing is held against the top of the journal while torquing. This will prevent the lower cap from having to draw the rod and piston assembly downward, thus flattening the Plastigage and giving a false reading.

WITHOUT TURNING THE CRANKSHAFT, remove the cap and check width of flattened Plastigage. The bearing in Fig. 16-99 has .0015 in. (0.038 mm) clearance. Note even width of flattened Plastigage indicating a straight journal. Wipe out Plastigage. Lubricate insert. Install cap and torque.

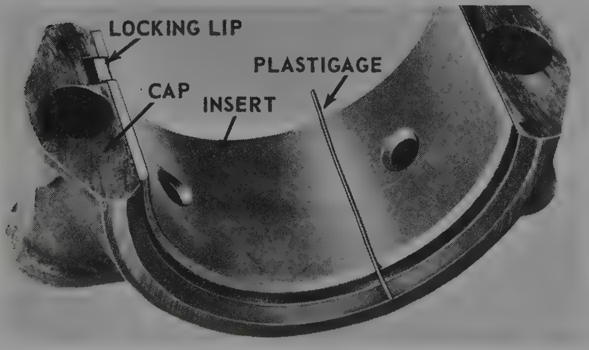

LOCKING LIP
CAP
INSERT
PLASTIGAGE

Fig. 16-98. Placing Plastigage across rod cap prior to checking bearing clearance. Cut strip to width of insert.

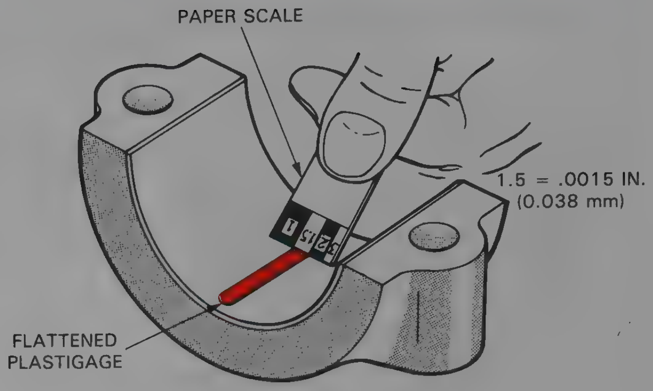

PAPER SCALE
1.5 = .0015 IN. (0.038 mm)
FLATTENED PLASTIGAGE

Fig. 16-99. Checking width of flattened Plastigage with paper scale. This strip indicates .0015 in. (0.038 mm) clearance. (Perfect Circle)

CHECKING CONNECTING ROD SIDE CLEARANCE

Following manufacturer's specifications (.004 to .010 in. or 0.102 to 0.254 mm average), check the connecting rod side play or clearance. Use a suitable feeler gauge. See Fig. 16-100.

Retorque all rods. Palnuts, if used, should be installed. Turn the crankshaft to make sure all parts are clear and that excessive drag is not present.

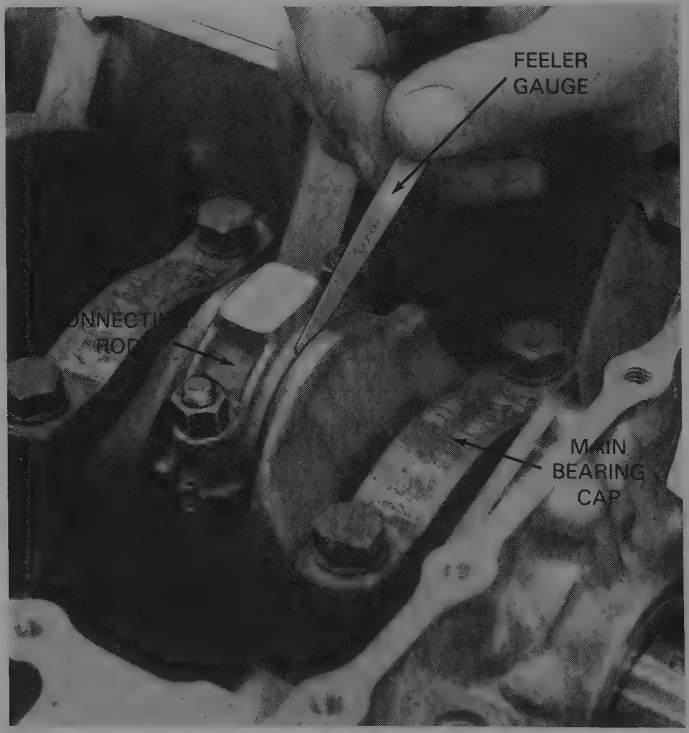

FEELER GAUGE
ONNECTI ROD
MAIN BEARING CAP

Fig. 16-100. Checking connecting rod side play or clearance. (Chevrolet)

SUMMARY—ENGINE BLOCK AND CYLINDERS

The block must be thoroughly cleaned and checked for warpage and cracks. Check camshaft and crankshaft bore sizes and alignment.

Remove cylinder ring ridge and measure cylinders for size, out-of-roundness, and taper. Check for scoring, scuffing, and cracks. Taper up to .012 in. (0.30 mm) and out-of-roundness not exceeding .005 in. (0.13 mm) should be considered maximum for reringing. Wear beyond this point will require reboring.

Cylinders should be deglazed (honed) to assist ring break-in. When reboring, rebore to the nearest standard oversize. Cylinders should be honed with 180 or 220 grit stones (for finishing) to produce a 20 to 30 micro inch finish.

Cylinders should be carefully cleaned with hot soapy water. Rinse with clear, hot water. Dry and oil at once.

SUMMARY—PISTONS

Clean pistons by soaking, then scraping. Do not use a wire brush. Use a suitable ring groove cleaner to remove carbon from grooves. Oil drain holes must be open. Check for wear, scoring, scuffing, and cracks.

A worn ring groove can be repaired by cutting it wider and installing a steel spacer.

Pistons may be resized by various methods, including knurling, cold expanding, and shot peening.

Proper piston-to-cylinder fit is important. The use of a feeler gauge strip and spring scale is a popular method of checking for correct clearance. When measuring pistons, measure across the skirt at right angles to the pin. If replacing one or more pistons, pistons used for replacement should weigh the same as the others in the engine.

Piston tops are generally marked so that they may be correctly installed. On some engines, pistons are not interchangeable from one bank to the other.

SUMMARY—PISTON PINS

Piston pins are retained by snap ring locks, are bolted to the piston, or bolted or press fitted to the rod.

Oversize pins should be fitted to piston and rod to remove excessive clearance. Honing or diamond boring are recommended. Accurate work is a MUST.

Before removing piston pins, determine correct relationship between piston and rod so they may be assembled together and in the correct way.

New bushings should be burnished before honing to secure them properly.

Never fit pins by feel or by using a reamer. A proper fit must be determined by careful measurement. Pin holes must be straight, smooth, round, and in perfect alignment. Following reconditioning, clean parts in hot, soapy water. Rinse, dry, and oil.

When snap ring end locks are replaced, install the open ends down. Lock must be in the groove and tight. When the pin is affixed to the rod, center it carefully to prevent scoring cylinder walls.

SUMMARY—RINGS

Ring sets are available in rebore (accurate cylinder) and oil control (worn cylinder) types. Rings must be of the correct width and of a size compatible with the cylinder. Check for proper end gap, clearance in the grooves, and groove depth.

Install rings as recommended by the manufacturer. Use a good ring expander. Space gaps around the piston. Lubricate thoroughly.

SUMMARY—CONNECTING RODS

Connecting rods should be numbered with upper and lower numbers on the same side. Ring ridge must be removed before pulling piston and rod assembly. Use rod bolt protectors to prevent damage to crankpin journal.

Rods must be checked for twist and bend. The big end bore must be round, straight, smooth, and of the correct size. Rods not meeting specifications must be replaced or reconditioned. Following reconditioning, wash with hot, soapy water. Rinse, dry, and lubricate.

When handling rods, do not subject them to any twisting or bending forces. Assemble rod to piston in original relationship.

Lubricate piston pin, rings, piston, cylinder, and upper rod insert prior to installing rod and piston assembly. Use a ring compressor and tap piston into cylinder. Check for proper bearing clearance, lubricate, and torque caps. Check for rod side clearance on the crankshaft journal.

CHECKLIST FOR BLOCK, CYLINDER, PISTON, RING, AND CONNECTING ROD SERVICE

Answers to the following questions should all be YES!

1. Is the cylinder block free of cracks and if not, have they been repaired?
2. Is the block head surface clean and within distortion limits?
3. Are the camshaft and main bearing bores round, of the correct size, and in proper alignment?
4. Has the block been thoroughly cleaned?
5. Are bolt hole threads clean and in good shape?
6. Was the "ring ridge" correctly removed?
7. Are the cylinders within taper and out-of-round limits?

8. Are the cylinders free of scuffing and scoring?
9. Were the cylinders honed to produce a 20-30 micro inch finish?
10. If rebored, were the cylinders honed?
11. Were the cylinders and crankcase thoroughly cleaned with hot, soapy water, and then dried and oiled?
12. Were the pistons properly cleaned and checked for cracks, scuffing, burning?
13. If the top groove was excessively worn, was it recut and fitted with a spacer?
14. If the old pistons were used, were they resized?
15. Were the pistons properly fitted to the cylinders?
16. Were the piston pin holes in good condition with the correct clearance?
17. Were bushings, when used, burnished before fitting?
18. If the pin is attached to the rod, is it properly centered and secured?
19. If snap ring end locks are used, are they properly installed?
20. Were pistons and rods assembled in the correct relationship to each other?
21. Are the rings of the correct style and size?
22. Is the ring end gap within specifications?
23. Is the ring side clearance in the groove satisfactory?
24. Are all ring grooves clean and in good condition?
25. Are the oil drain holes in the oil ring groove open?
26. Are the ring grooves of the correct depth for the rings?
27. Are the rings correctly installed?
28. Are the connecting rods correctly marked?
29. Are the connecting rod big end bearing bores smooth, round, straight, and of the correct size?
30. Are the connecting rods free of bend, twist, and unwanted offset?
31. Are the rod bearing-to-journal clearances as specified?
32. Are rod side clearances within limits?
33. Are journals round, straight, and smooth?
34. Do rod bearing inserts have proper "spread" and "crush" and are the locking lips in place?
35. Is the rod bearing cap number the same as the upper bore number and are they on the same side?
36. Were bearing caps torqued?
37. If bearing bolt locking devices are used, are they in good shape and correctly installed?
38. Are pistons and rods assembled correctly and are they installed in the proper cylinders, facing in the correct direction?
39. Were the crankshaft rod journals protected from damage during rod and piston installation?
40. Were all parts lubricated upon assembly and lubricated again prior to installation?
41. Were all fasteners properly torqued?
42. Does the crankshaft turn over without excessive drag?

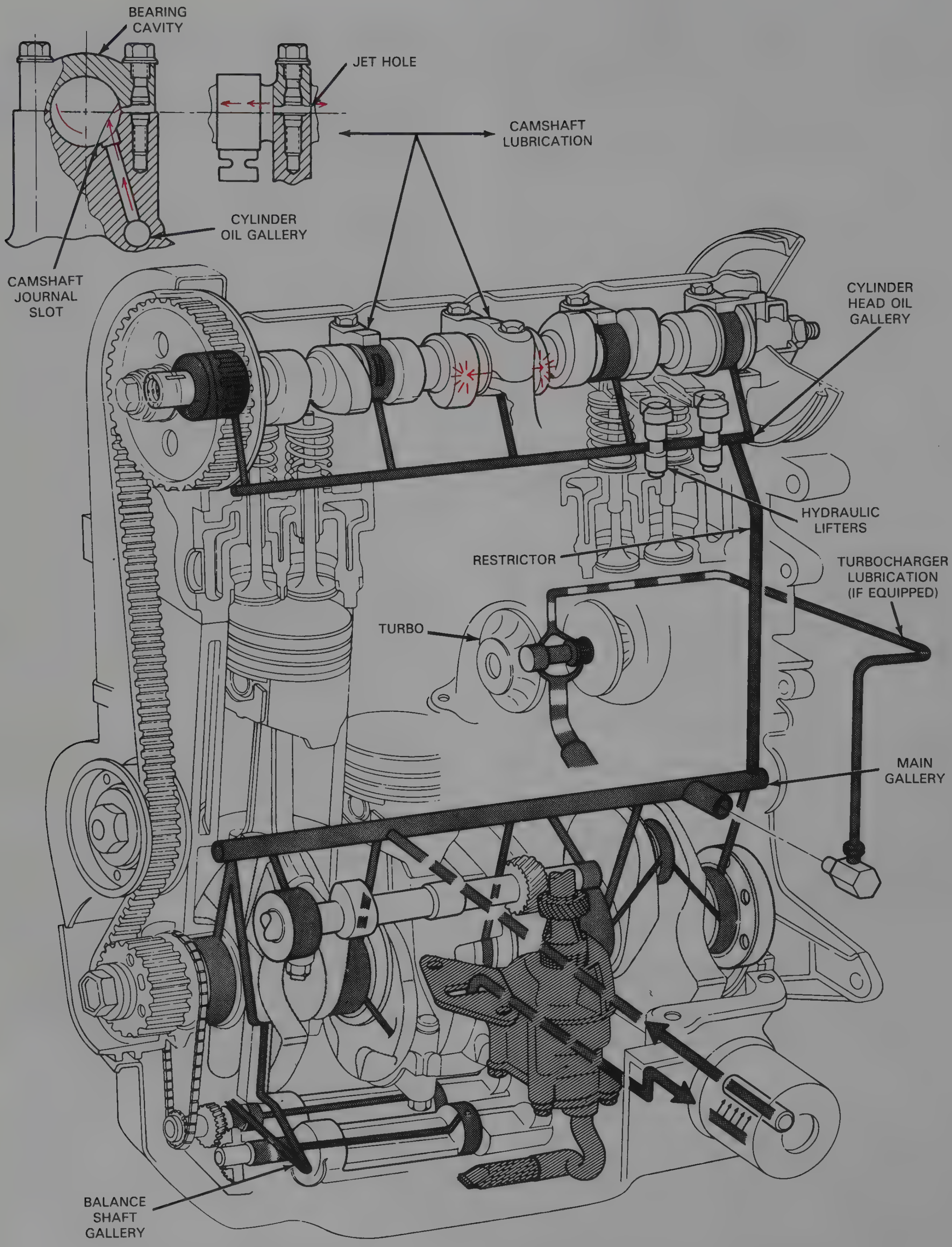
KNOW THESE TERMS

Engine block, Block distortion, Head mating surface, Resurfacing, Main bearing bore, Ring ridge, Ring travel, Taper, Out-of-round, Engine centerline, Ring ridge reamer, Rebore, Cylinder sleeve, Deglazing, Oversize bore, Cylinder dial gauge, Ring float, TDC, Piston slap, Ring break-in, Honing, Micro inch, Boring bar, Sleeve, Piston skirt, Ring groove cleaner, Ring groove spacer, Pin boss, Knurling, Skirt collapse, Shot peening, Full floating piston pin, Piston pin fit, Oversize pin, Pin fitting, Interference fit, Rod heater, Rings, Ring gap, Piston ring groove depth, Ring side clearance, Ring expander, Connecting rod, BDC, Connecting rod twist, Rod spit hole, Ring compressor, Connecting rod side play, Rod bearing clearance.

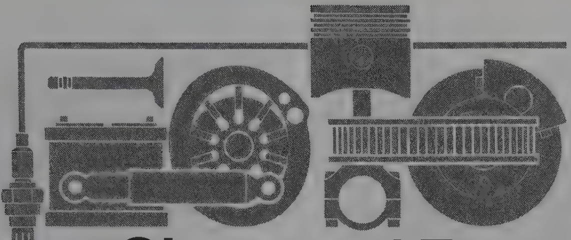
QUIZ - Chapter 16

1. Cylinder block and cylinder head mating surfaces are:
   - [✓ a.] Never warped.
   - b. Seldom warped.
   - c. Often warped.
   - d. Always warped.
2. When removing the ring ridge, be certain to undercut into the cylinder wall. [✓ True] or False?
3. Cylinder wear is greatest at:
   - a. The bottom of the ring travel.
   - b. The center of the ring travel.
   - [✓ c.] The top of the ring travel.
4. Taper is the difference between the diameter at the top of the cylinder and the diameter at the bottom of the ring travel.
5. If the ring ridge is not removed:
   - a. The rings will not seat properly.
   - b. The cylinder walls will be distorted.
   - [✓ c.] The top ring and piston can be broken.
   - d. The piston will be hard to install.
6. Taper exceeding 012 requires reboring the cylinder.
7. Cylinder out-of-roundness should not exceed 005.
8. Cylinders must be deglazed or honed before installing new rings. [✓ True] or False?
9. Cylinders do not have to be honed following reboring. True or False?
10. A 2030 to 15 25 micro inch cylinder surface is right for proper ring break-in.
11. 180 or 220 grit honing stones will produce the desired micro inch surface.
12. When honing worn cylinders, always:
    - a. Hone at the top.
    - b. Hone at the bottom.
    - [✓ c.] Start honing at bottom then work up cylinder.
    - d. Start honing at top then work down into cylinder.

13. Worn cylinders must be honed until ALL the glazed surface is removed. [✓ True] or False?
14. Common oversizes for reboring cylinders are: 10, 20, 30, and 40 in.
15. After a cylinder is reconditioned, it should be cleaned first by wiping with an oily rag. True or [✓ False?]
16. A power wire brush is excellent for cleaning piston ring grooves. True or False?
17. Worn top rings can be repaired by recutting and installing a thin steel ____________.
18. Heavy score marks on pistons require:
    a. Scrapping the pistons.
    b. Filing to remove marks.
    c. Knurling.
19. Slightly worn pistons can often be resized thus allowing further service. True or False?
20. Pistons are often fitted to the cylinders by using a __________ __________ and a spring scale.
21. Worn piston pin bores in the rod or piston require:
    a. Scrapping the unit.
    [✓ b.] Fitting to an oversize pin.
    c. Pin expansion by knurling.
22. A typical pin fit in an aluminum piston would have the following clearance:
    a. .002 to .004 in. (0.05 to 0.10 mm).
    [✓ b.] .0002 to .0005 in. (0.0051 to 0.0127 mm).
    c. .020 to .0205 in. (0.51 to 0.5207 mm).
    d. .006 to .010 in. (0.15 to 0.25 mm).
23. Pin holes are best reconditioned by careful reaming. True or [✓ False?]
24. After installing a pin bushing, but before fitting, it should be ____________.
25. Piston pin holes must be __________, __________, __________, and of the correct diameter.
26. The lower piston ring groove contains the compression ring. True or [✓ False?]
27. The clearance between the ends of the ring when installed in the cylinder is referred to as ring gap.
28. Normally, .020 in. (0.51 mm) oversize rings will function in cylinders:
    a. Standard to .020 in. (0.51 mm) over.
    b. .010 to .030 in. (0.25 to 0.76 mm) over.
    [✓ c.] .020 in. (0.51 mm) over.
    d. .020 to .040 in. (0.51 to 1.01 mm) over.
29. Taper face rings should be installed so that the widest edge faces down.
30. The ends of the oil ring expanders must be lapped over each other. True or [✓ False?]
31. When installing rings on the piston, install the oil control ring first.
32. The gaps on all rings must be aligned. True or [✓ False?]
33. Rings should be checked for ring gap, side Clearance, and proper size.
34. Before removing connecting rods, check for proper Marks on both upper and lower bore halves.
35. To prevent damage to the crankshaft journal when removing or installing rods, protector ____________ ____________ should be used.
36. Rods can become bent or twisted in normal service. [✓ True] or False?
37. Rod bend and rod twist are best removed by heating. True or [✓ False?]
38. Connecting rod big end bore elongation is corrected by:
    a. Honing to a suitable oversize.
    [✓ b.] Reducing diameter by removing stock from the parting surfaces and then honing to standard.
    c. Knurling.
    d. Building up with arc welding then boring to standard.
39. If the crankshaft journal is .0015 in. out-of-round and the rod bore is .002 in. out-of-round and the bearing is fitted so that the minimum clearance is .002 in., what would the maximum clearance be? 035
40. It is necessary to use a ring compressor to install the piston and rod assemblies.
41. Connecting rod bearing to crankshaft journal clearance is best determined by using a feeler gauge. True or [✓ False?]
42. Pistons are always interchangeable from one bank to the other. True or [✓ False?]
43. Pistons are always interchangeable between cylinders on any one bank. True or [✓ False?]
44. Most oversize pistons will have the amount of oversize stamped on the top of the piston.


BEARING CAVITY
JET HOLE
CAMSHAFT LUBRICATION
CYLINDER OIL GALLERY
CAMSHAFT JOURNAL SLOT
CYLINDER HEAD OIL GALLERY
HYDRAULIC LIFTERS
RESTRICTOR
TURBOCHARGER LUBRICATION (IF EQUIPPED)
TURBO
MAIN GALLERY
BALANCE SHAFT GALLERY

Engine lubrication system used on a four-cylinder, turbocharged engine. (Chrysler)



Chapter 17

ENGINE LUBRICATION

After studying this chapter, you will be able to:

☐ List the basic parts of a lubrication system.
☐ Describe oil pump service.
☐ Explain oil filtration systems and their service.
☐ Describe oil classifications.

The importance of a properly functioning engine lubrication system cannot be overemphasized. An ample supply of clean oil of the correct grade and viscosity must reach all bearing surfaces.

The basic parts of the lubrication system are the oil sump or pan, oil pickup, pump, relief valve, distribution lines, filter, bypass valve, and oil pressure sending unit. The path of the oil from the sump to the various moving parts in the typical lubrication system is shown in Fig. 17-1. Trace the flow.

OIL PICKUP

The oil pickup can be the floating type in which the pickup tube allows the float to follow the level of the oil in the pan, Fig. 17-2. Or, it can be the commonly used fixed type, which has a definite setting. With the fixed type, the setting should be carefully checked for proper depth, Fig. 17-3.

PICKUP TUBE SCREEN

The end of the pickup tube is screened to prevent large particles from entering the system. The screen has a tendency to clog with sludge if the engine oil is not serviced properly. See Fig. 17-4.

Lubrication systems are usually provided with a check valve that allows oil to bypass the screen if clogged, thus preventing oil starvation (serious oil shortage). When the screen is clogged and the valve opens, large particles of dirt and chunks of sludge can be drawn into the system. This condition should be avoided.

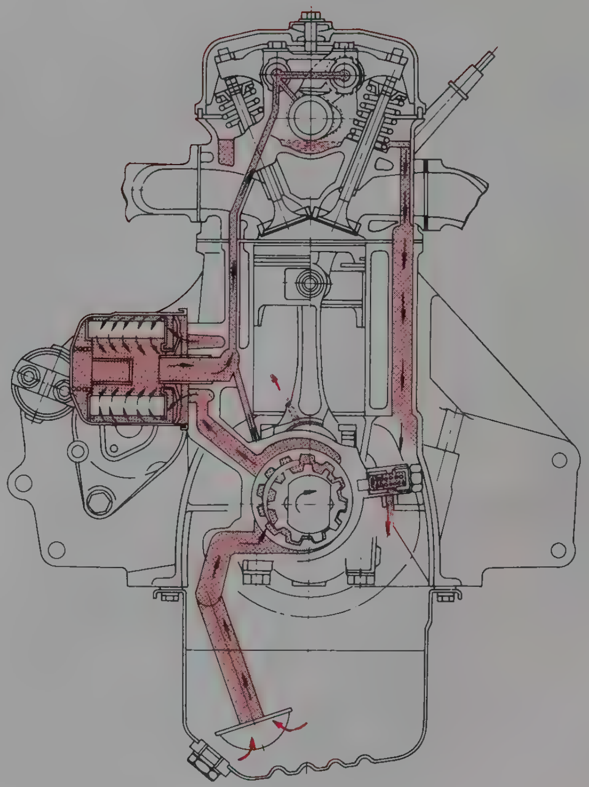


Fig. 17-1. Typical lubrication system. Filter is full-flow, spin-on type. (Chevrolet)

OIL PICKUP SCREENS MAY BE CLEANED BY SOAKING UNIT IN CARBURETOR CLEANER. RINSE AND BLOW DRY. BE CAREFUL NOT TO DISTORT OR DAMAGE SCREEN.

Pickup screens generally have a thin stamped steel baffle that partially covers the screen. This prevents temporary oil starvation during violent surging of the sump oil supply. IF THE BAFFLE IS REMOVED, IT MUST BE REPLACED IN THE PROPER POSITION.

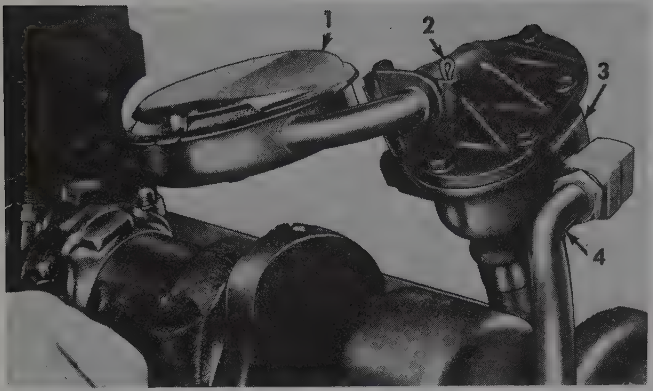


Fig. 17-2. Floating type oil pickup. Pickup rides on top of motor oil. If oil level drops, pickup swings down. 1. Oil intake float assembly. 2. Cotter pin. 3. Oil pump assembly. 4. Pump-to-cylinder block tube. (GMC)

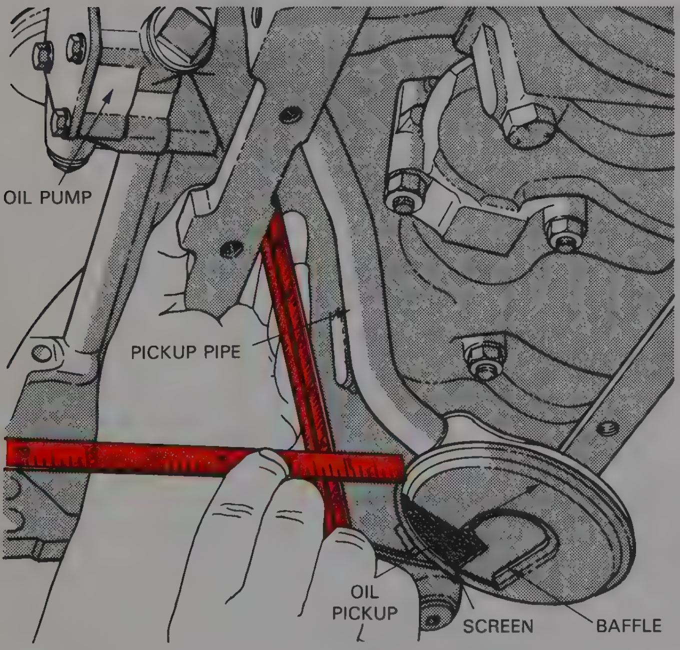


Fig. 17-3. Checking oil pickup tube and screen for correct position. (Chrysler)

OIL PUMP SHOULD BE CHECKED FOR WEAR

Far too often, mechanics take the oil pump for granted and fail to check it for wear. Despite the fact that the oil pump is obviously heavily lubricated, after a period of long operation enough wear may occur to seriously affect pump performance. DURING AN OVERHAUL, ALWAYS CHECK THE OIL PUMP FOR WEAR.

OIL PUMP REMOVAL

When the oil pump drive shaft contains a drive gear that also turns the distributor, the ignition timing will be thrown off when the pump and gear are pulled. It is often desirable to turn the engine until the number one piston is near the top of the firing stroke. Stop when the timing pointer is aligned with the proper ignition timing mark on the engine front pulley or damper. (See Chapter 21 on ignition for details on timing and installing distributor.) At this point, the distributor rotor should be pointing to the number one cylinder wire tower with the points just starting to open. Mark the distributor body with chalk directly in line with the rotor.

Fig. 17-4. This oil screen is badly clogged. (Chrysler)

Remove the oil pump. While it is off, do not rotate the engine. When installing, make sure the rotor is aligned with the chalk marks when the oil pump is fully seated. If it is not, pull the pump out far enough to turn the shaft and gear one or more teeth as required. Keep trying until the pump is seated and the rotor is aligned properly. Make sure the engine timing marks are still aligned.

If the oil pump is driven by a slot in the distributor shaft, Fig. 17-5, or if driven by a gear that does not connect to the distributor shaft, Fig. 17-6, the timing will not be affected when the pump is removed.

If in doubt as to what effect the pump removal has on ignition timing, bring the number one piston into position as outlined. Mark the rotor position, pull the pump and try to turn the rotor. If the pump drives the distributor, the rotor will turn freely. If the distributor drives the pump or is driven by a separate gear, the rotor will not turn.

PUMP DISASSEMBLY

After removing the pump cover, but before pulling either rotors or gears, mark the units with a sharp scribe. Then when reassembled, the same ends face the

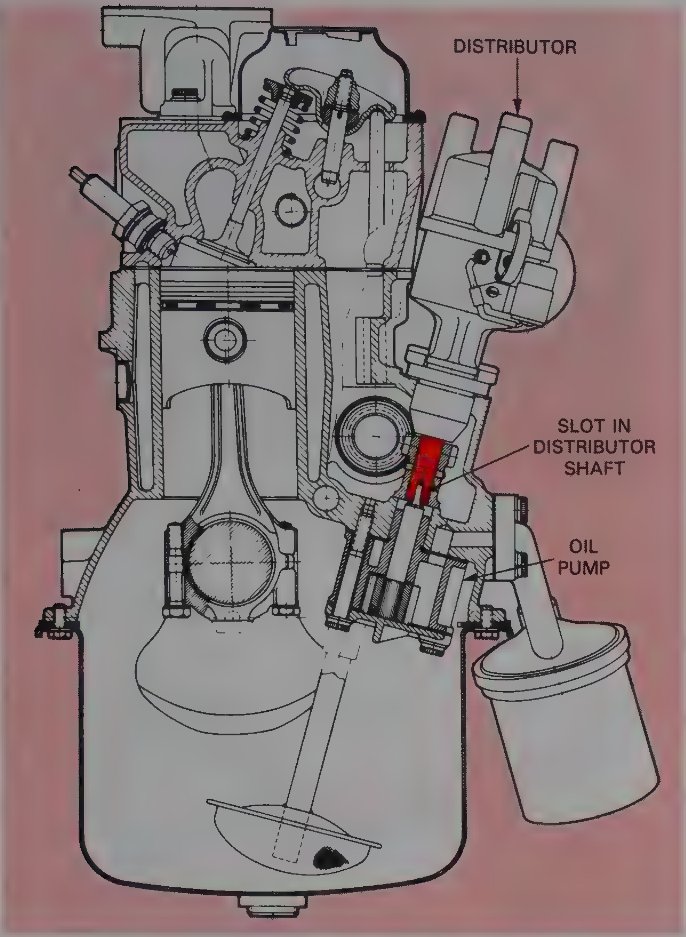


Fig. 17-5. A slot in the end of distributor drive shaft can be used to turn oil pump shaft. In this setup, removing oil pump will not alter ignition timing. (General Motors)

cover plate. Both units should mesh with each other in the same position. Note the scribe marks on the rotors in Fig. 17-8. If a gear is affixed to the shaft, drive the pin out of the gear before trying to remove the shaft.

CHECK ROTOR TYPE OIL PUMP FOR WEAR

A typical rotor type oil pump is pictured in Fig. 17-7. Note that the pump contains an oil pressure relief valve. This particular pump drives the distributor shaft.

Check the end clearance of both inner and outer rotors by placing a straightedge across the pump body and passing a suitable feeler gauge (.004 in. or 0.10 mm considered maximum) between the straightedge and rotor surfaces, Fig. 17-8. The type of gasket, if any, between pump body and cover, must be considered when checking end clearance. The pump type shown in Fig. 17-8 can use a neoprene O-ring seal that allows metal-to-metal contact. The measured clearance between rotors and body is actual end clearance. If a thin gasket is used, the thickness of the compressed gasket must be added to the feeler gauge reading.

When the end clearance is excessive, to determine if the wear is in the pump body or in the rotors, measure the length of both inner and outer rotors. Use manufacturers' wear limit specifications. See Figs. 17-9 and 17-10.

Use a feeler gauge to check the clearance between the outer rotor and pump body (.012 in. or 0.30 mm considered maximum). See Fig. 17-11.

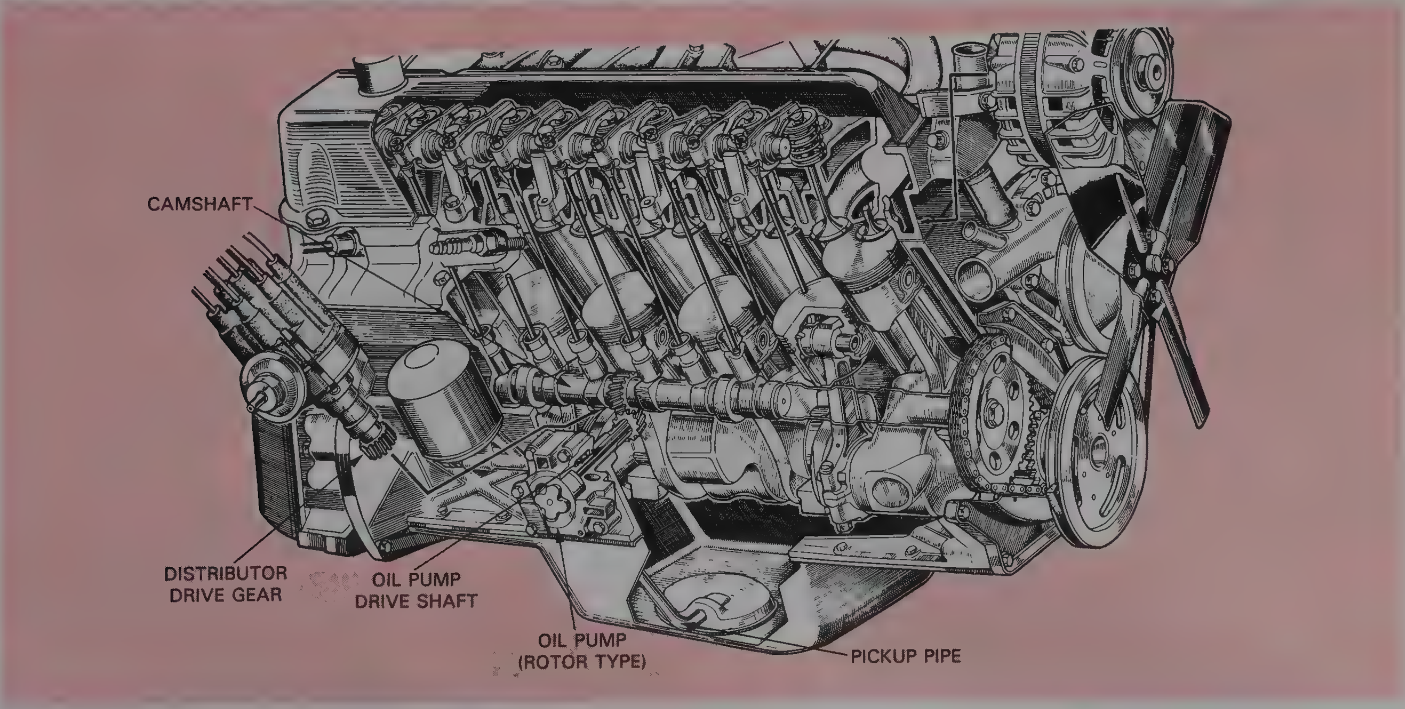


Fig. 17-6. Oil pump and distributor are not connected. Oil pickup is of fixed design. (Plymouth)

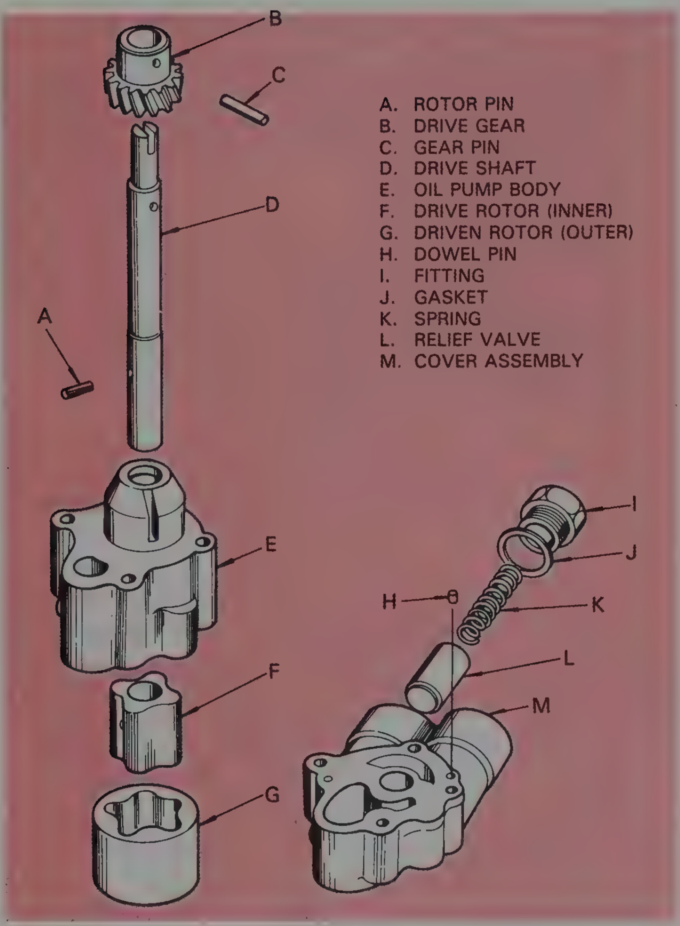

A. ROTOR PIN
B. DRIVE GEAR
C. GEAR PIN
D. DRIVE SHAFT
E. OIL PUMP BODY
F. DRIVE ROTOR (INNER)
G. DRIVEN ROTOR (OUTER)
H. DOWEL PIN
I. FITTING
J. GASKET
K. SPRING
L. RELIEF VALVE
M. COVER ASSEMBLY
A
B
C
D
E
F
G
H
I
J
K
L
M

Fig. 17-7. Typical rotor type oil pump. (Chevrolet)

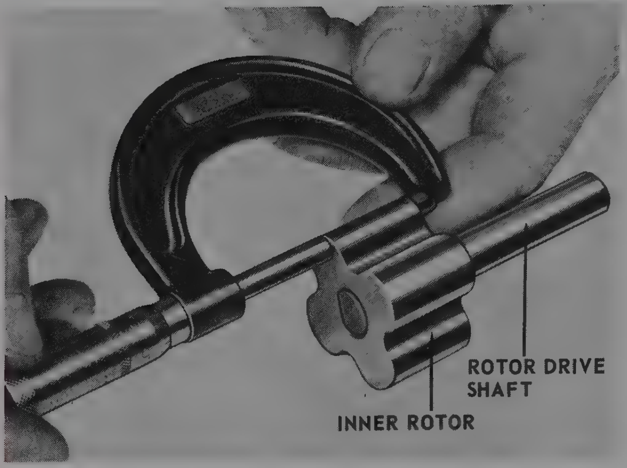

ROTOR DRIVE SHAFT
INNER ROTOR

Fig. 17-9. Measuring inner rotor length. (Dodge)

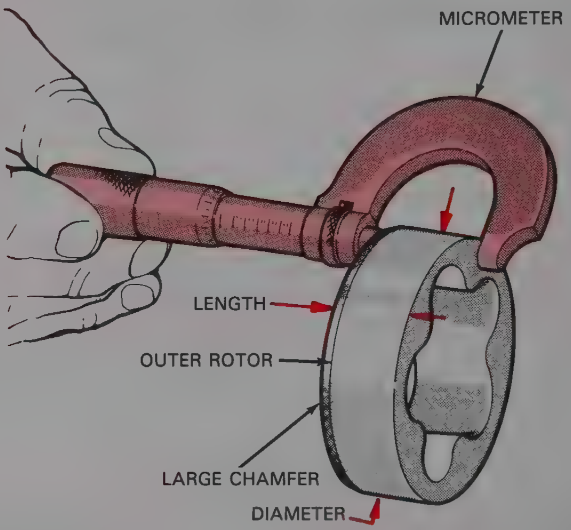

MICROMETER
LENGTH
OUTER ROTOR
LARGE CHAMFER
DIAMETER

Fig. 17-10. Measuring outer rotor length. (Chrysler)

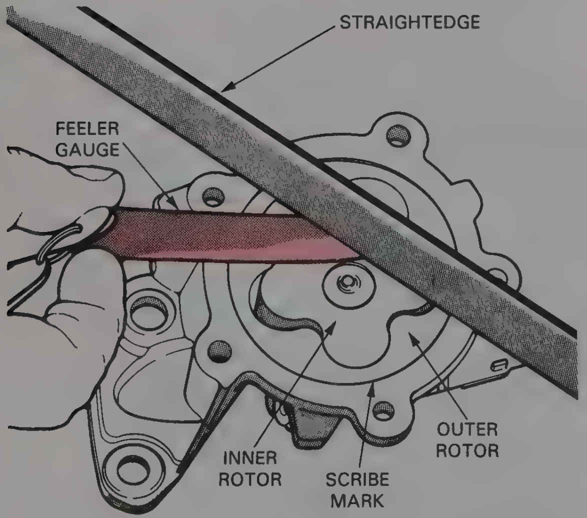

STRAIGHTEDGE
FEELER GAUGE
INNER ROTOR
SCRIBE MARK
OUTER ROTOR

Fig. 17-8. Checking rotor end clearance. Note light scribe mark. (Chrysler)

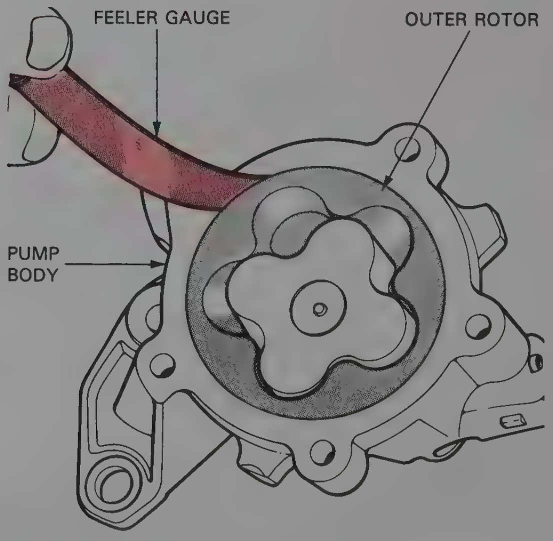

FEELER GAUGE
OUTER ROTOR
PUMP BODY

Fig. 17-11. Checking outer rotor-to-pump body clearance. (Chrysler)

Check the tip clearance between inner and outer rotors (.010 in. or 0.25 mm considered maximum). See Fig. 17-12.

Place a straightedge on the cover and with a feeler

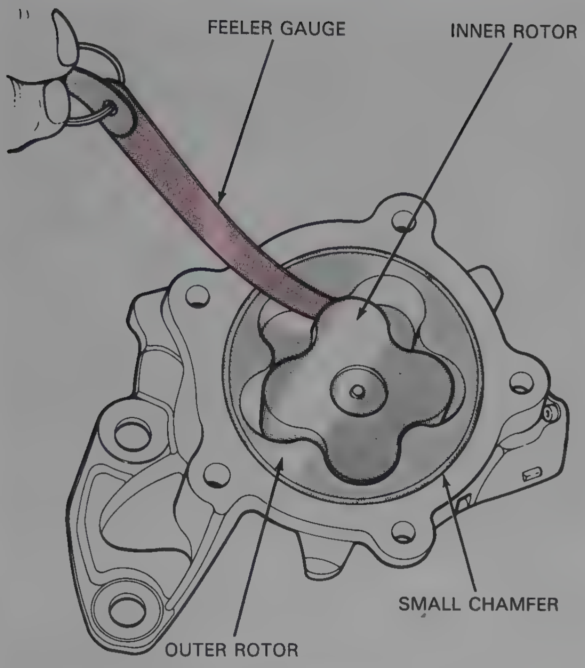


Fig. 17-12. Checking tip clearance between rotors. (Chrysler)

gauge, determine cover wear (.0015 in. or 0.038 mm considered maximum). See Fig. 17-13.

The inner rotor shaft-to-body bearing clearance should also be checked (.001-.003 in. or 0.025-0.08 mm average range). This can best be done by careful measurement of the shaft and bearing hole. Inspect rotors and shaft for scoring, galling, and chipping. Check pump body for cracks.

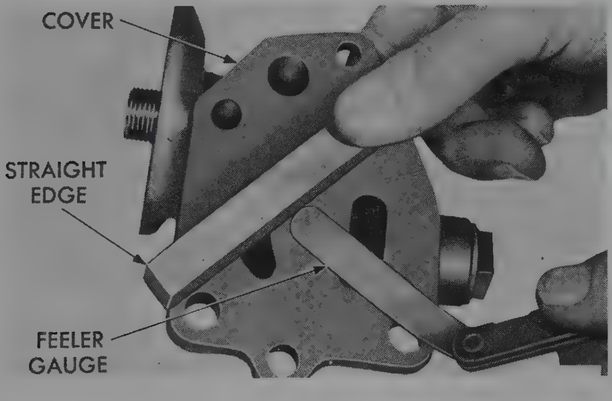


Fig. 17-13. Checking pump cover for wear.

When needed, replace rotors as a PAIR. NEVER REPLACE ONE ROTOR.

Remember that to function properly, the rotor pump working clearances between inner and outer rotor, between outer rotor and pump body, and between rotor ends and pump cover must be within specified limits.

CHECKING GEAR TYPE OIL PUMP FOR WEAR

Study the exploded view of the typical gear type oil pump, Fig. 17-14. Note that the driving gear (F) is attached to a drive shaft while the idler or driven gear revolves around a fixed shaft. This pump also incorporates a pressure relief valve.

Use a straightedge and feeler gauge to check end clearance between gears and pump body (.004 in. or 0.10 mm maximum—remember gasket effect on clearance). See Fig. 17-15.

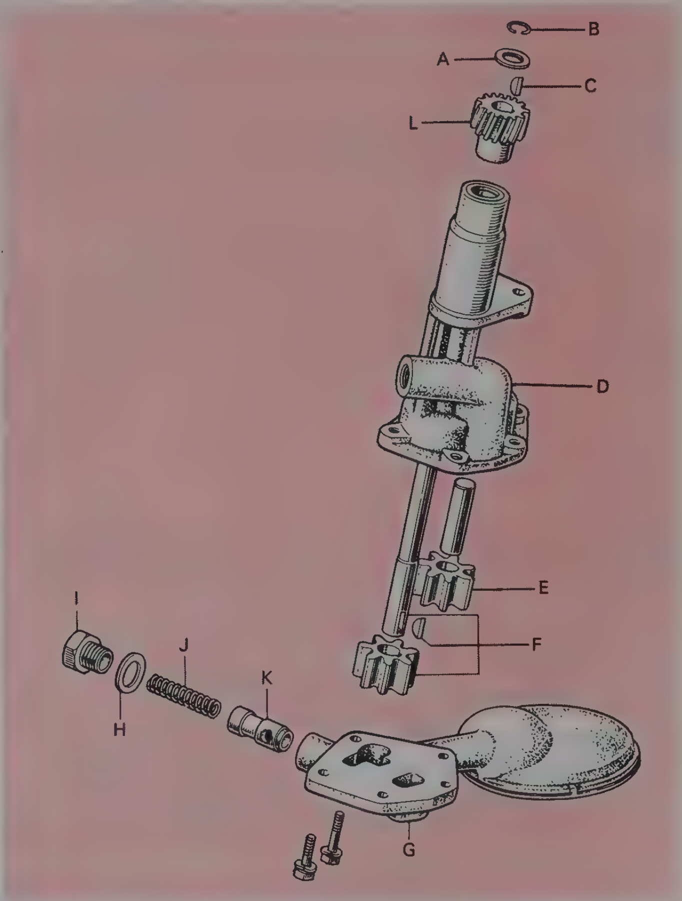


Fig. 17-14. Typical gear type oil pump. A—Spacer. B—Snap ring. C—Woodruff key. D—Oil pump body. E—Driven gear. F—Driving gear. G—Cover. H—Gasket. I—Plug. J—Relief valve spring. K—Relief valve. L—Oil pump drive shaft gear. (Toyota)

Check clearance between gear teeth and pump body.

A narrow feeler or a dial indicator can be used to check the backlash (play) between the two gears (.015 in. or 0.38 mm maximum). Drive shaft-to-shaft bearing clearance should not exceed .003 in. (0.08 mm).

Fig. 17-15 illustrates pump gear end clearance being checked with a straightedge and feeler gauge. No gasket is used when measuring this particular pump. Some require that a gasket be in position BEFORE measuring.

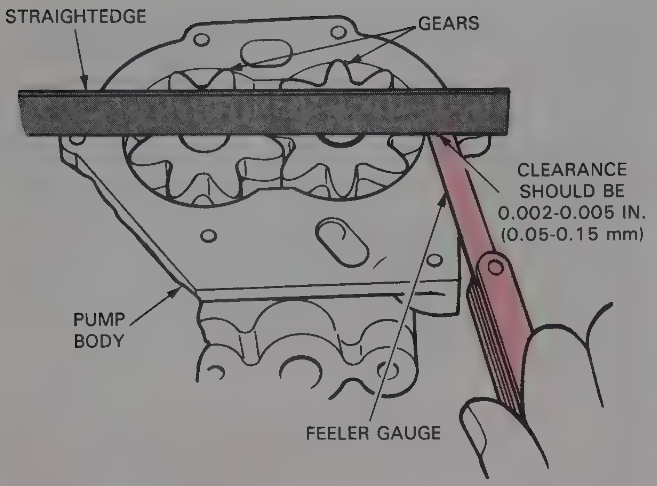


Fig. 17-15. Checking pump gear end clearance. No gasket is in place on this particular pump. Others require a gasket to be in position. (Ford)

Follow manufacturer's recommendations.

Use a feeler gauge to check the clearance between the gear teeth (use tip of tooth) and the pump body. See Fig. 17-16.

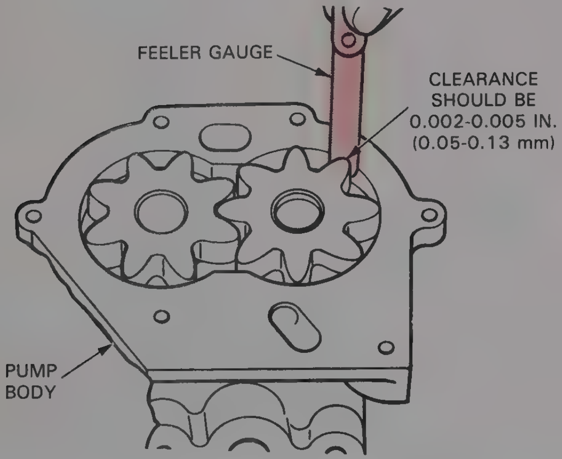


Fig. 17-16. Checking gear tooth tip-to-pump body clearance. (Ford)

Check the backlash between the gear teeth with a feeler gauge. It will generally run within .002 to .008 in. (0.05 to 0.20 mm). If backlash is not within recommended limits, replace BOTH gears as a pair, Fig. 17-17.

Next, check the pump cover for flatness. This is done by using a straightedge and feeler gauge as shown in Fig. 17-18. A wear depth of .002 in. (0.05 mm) is generally the maximum allowable. If the cover is not within this specification, it can be sanded down on the face with 400 grit or finer paper on a FLAT surface.

After sanding, polish surface with crocus cloth to remove scratches. Then clean thoroughly, Fig. 17-18.

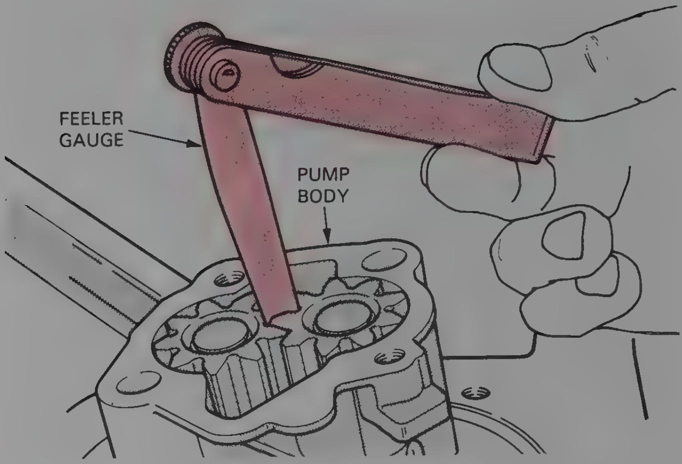


Fig. 17-17. Checking gear pump tooth backlash. Excessive lash impairs pump efficiency. (Chrysler)

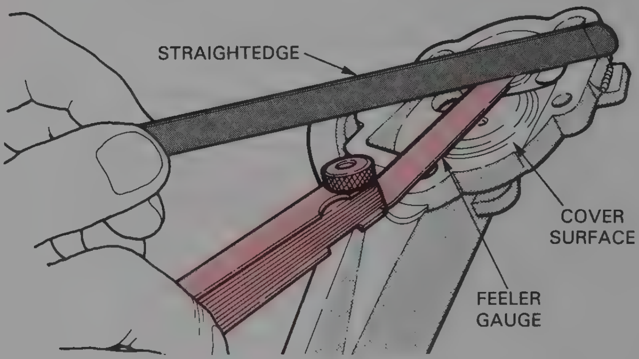


Fig. 17-18. Using a straightedge and feeler gauge to check oil pump cover flatness. (Chrysler)

Other gear pump check points include: gear tooth wear, scoring, and chipping. Check pump body and cover for cracks. Also, clean and check relief valve.

A quick check for end clearance between either gears or rotors and the cover plate, can be accomplished by placing a strip of Plastigage across the face of the units. Then bolt the cover in place. Without turning the gears, remove cover and check flattened Plastigage which shows the clearance. See Fig. 17-19.

A different type of gear oil pump is pictured in Fig. 17-20. You will note that it uses an internal gear driven by an external gear. This particular pump mounts directly to the engine and is driven by the crankshaft, Fig. 17-20.

PUMP ASSEMBLY

All pump parts must be spotlessly clean. Lubricate shafts and gear or rotor. Install parts, gaskets, and tighten all fasteners. Before putting the pump into position, fill the gear or rotor cavities with engine oil.

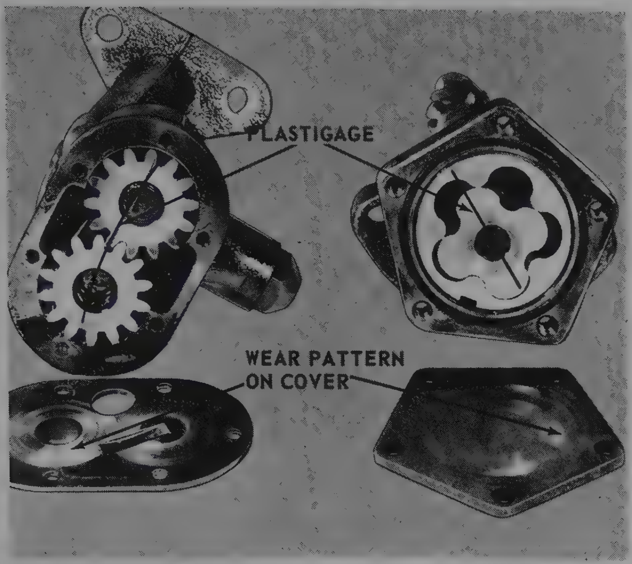

PLASTIGAGE
WEAR PATTERN
ON COVER

Fig. 17-19. Using Plastigage to check clearance between gear and rotor units, and their respective covers. (Perfect Circle)

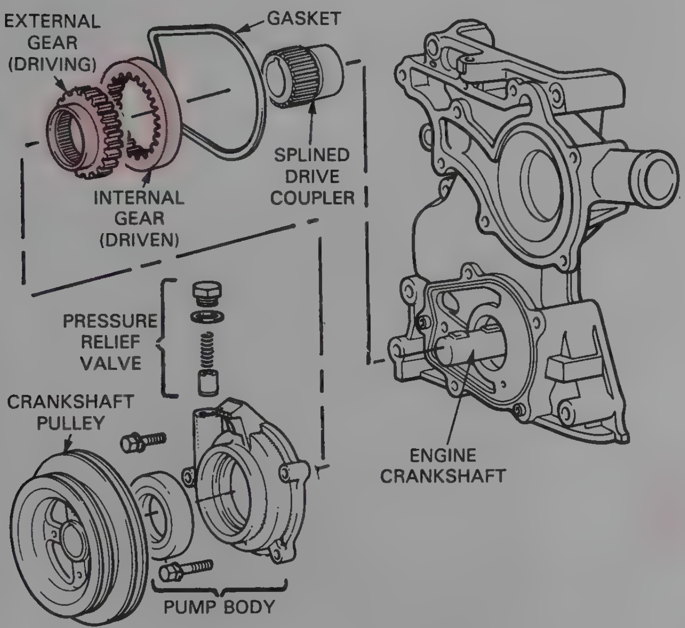

EXTERNAL
GEAR
(DRIVING)
GASKET
SPLINED
DRIVE
COUPLER
INTERNAL
GEAR
(DRIVEN)
PRESSURE
RELIEF
VALVE
CRANKSHAFT
PULLEY
ENGINE
CRANKSHAFT
PUMP BODY

Fig. 17-20. Oil pump using an internal (driven) and external (driving) gear setup. Driving gear is splined to end of crankshaft. (Toyota)

BEFORE STARTING AN ENGINE FOLLOWING AN OVERHAUL, THE LUBRICATION SYSTEM SHOULD BE CHARGED WITH OIL UNDER PRESSURE. (The pressurizing procedure is described in Chapter 18 on engine installation and break in.) This will assist the pump in priming itself (drawing a vacuum and pulling oil from sump). One manufacturer recommends packing the pump with petroleum jelly to make sure it primes. NEVER USE CHASSIS LUBE FOR THIS PURPOSE.

If a drive gear, pinned to the shaft, was removed, make certain a new pin is in place and properly peened. The pump drive shaft should turn FREELY.

PUMP INSTALLATION

Install the pump carefully. If ignition timing is affected, proceed as outlined earlier in this chapter. Clean and attach any external lines. Check pickup tube and screen positioning. Make certain pump is firmly attached. Also check that any gaskets or seal rings are in good condition and properly positioned. See Fig. 17-21.

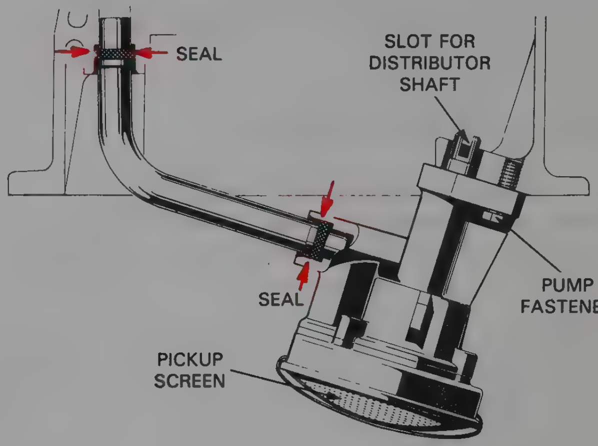

SEAL
SLOT FOR
DISTRIBUTOR
SHAFT
SEAL
PUMP
FASTENER
PICKUP
SCREEN

Fig. 17-21. Be careful when installing an oil pump. Make certain that all fittings, fasteners, seals, and gaskets are in good condition and properly located. If adjustable, check pump pickup height. (Volvo)

PRESSURE RELIEF VALVE

A pressure relief valve is incorporated in the lubrication system to limit maximum pressures. The valve may be part of the pump or can be built into the block. See Fig. 17-22.

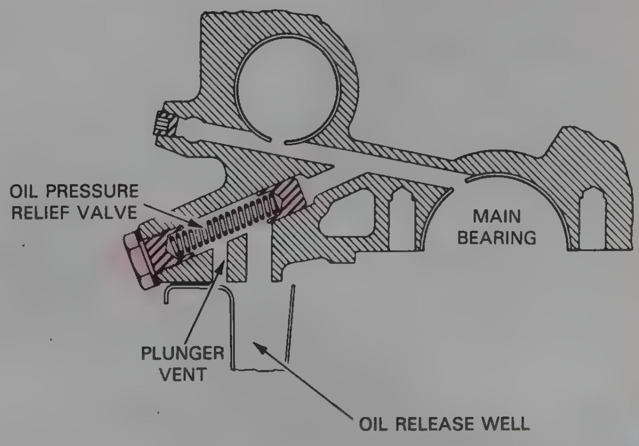

OIL PRESSURE
RELIEF VALVE
MAIN
BEARING
PLUNGER
VENT
OIL RELEASE WELL

Fig. 17-22. A pressure relief valve built into block. (Clevite)

The pressure relief valve should be disassembled, cleaned, and checked. Check spring for "free" length (length of spring when not under pressure). If specified, check pressure when compressed to a specified length. Inspect fit of plunger valve in the bore. Plunger and bore must be free of scoring. Crocus cloth may be used to remove carbon and minor scratches from both bore and plunger. The idea is to clean and smooth while removing VERY LITTLE metal.

Relief valve pressure control will be altered by any change in spring length, either by stretching or by adding or subtracting shims.

NEVER STRETCH THE SPRING. IF IT DOES NOT MEET SPECIFICATIONS–REPLACE IT.

Rinse, dry, lubricate, and assemble the valve. See Fig. 17-23.

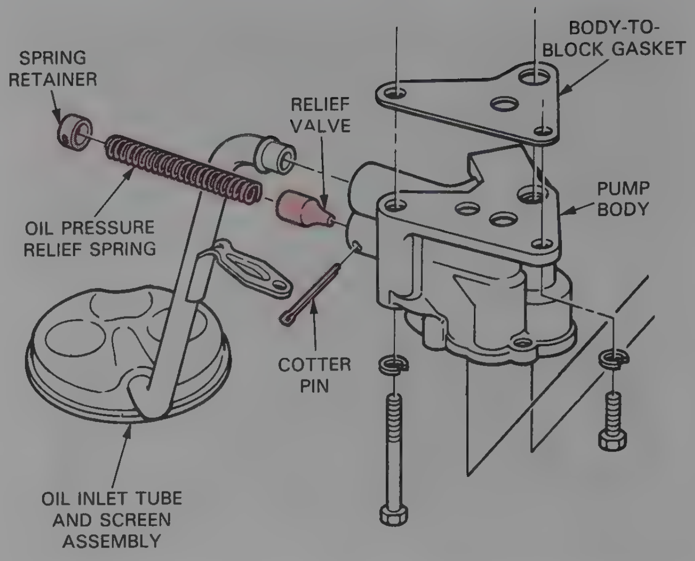

SPRING RETAINER
OIL PRESSURE RELIEF SPRING
RELIEF VALVE
BODY-TO-BLOCK GASKET
PUMP BODY
COTTER PIN
OIL INLET TUBE AND SCREEN ASSEMBLY

Fig. 17-23. Oil pump oil pressure relief valve parts. Parts and bore must be clean. Assemble in proper order. (AMC)

OIL DISTRIBUTION PASSAGES

During a major overhaul, it is imperative that all oil galleries be cleaned. This is best done by removing gallery end plugs before "boiling out" the block in a cleaning solution. All passageways should be "rodded out" with a rifle brush, rinsed, and blown dry. ANY DIRT, SLUDGE, OR PARTICLES LEFT IN THE DISTRIBUTION SYSTEM WILL BE PUMPED INTO THE BEARINGS WITH DISASTROUS RESULTS. Replace and tighten all plugs.

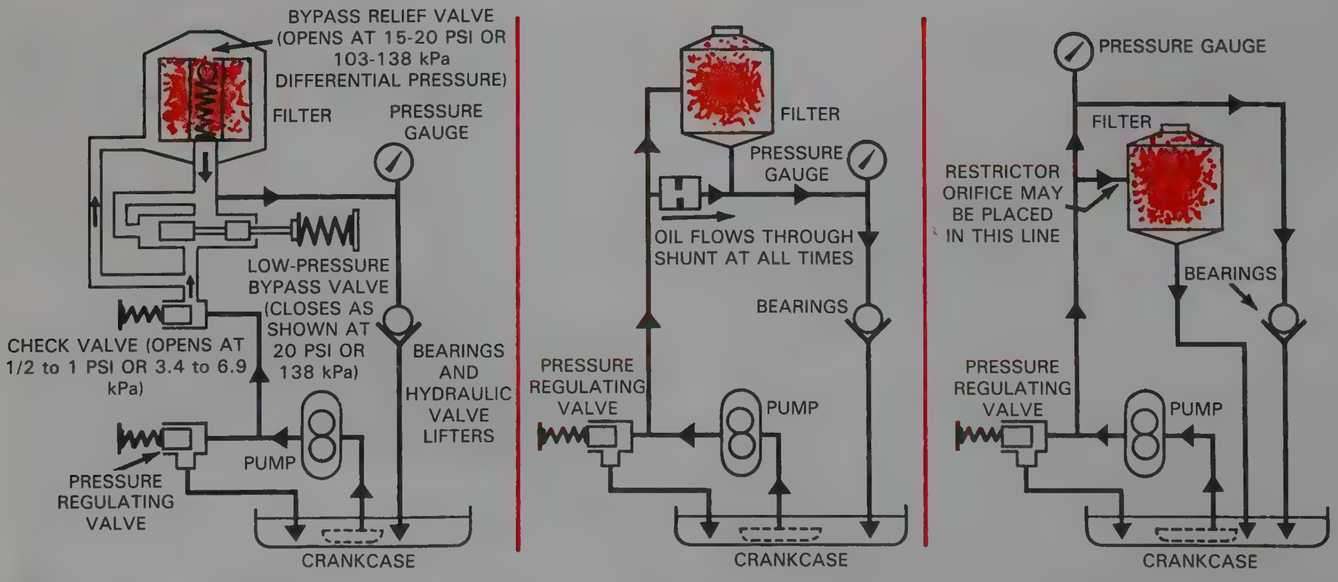
OIL FILTRATION SYSTEMS

Three basic oil filtration systems are schematically illustrated in Fig. 17-24. The FULL-FLOW SYSTEM is the most widely used. It has the advantage of filtering ALL oil before it reaches the bearings.

The SHUNT SYSTEM delivers some oil directly from the sump to the bearings. The oil passing through the filter is also delivered to the bearings.

The BYPASS SETUP delivers oil directly from sump to bearings. Oil passing through the filter is returned to the sump. Oil in the sump must be circulated through the system about ten times in order to filter ALL the oil ONCE.

Study the various parts shown in the popular full-


BYPASS RELIEF VALVE (OPENS AT 15-20 PSI OR 103-138 kPa DIFFERENTIAL PRESSURE)
FILTER
PRESSURE GAUGE
LOW-PRESSURE BYPASS VALVE (CLOSES AS SHOWN AT 20 PSI OR 138 kPa)
CHECK VALVE (OPENS AT 1/2 to 1 PSI OR 3.4 to 6.9 kPa)
BEARINGS AND HYDRAULIC VALVE LIFTERS
PUMP
PRESSURE REGULATING VALVE
CRANKCASE
FILTER
PRESSURE GAUGE
OIL FLOWS THROUGH SHUNT AT ALL TIMES
BEARINGS
PRESSURE REGULATING VALVE
PUMP
CRANKCASE
PRESSURE GAUGE
FILTER
RESTRICTOR ORIFICE MAY BE PLACED IN THIS LINE
BEARINGS
PRESSURE REGULATING VALVE
PUMP
CRANKCASE

A TYPICAL FULL-FLOW FILTRATION SYSTEM

SHUNT-TYPE LUBRICATING OIL FILTRATION SYSTEM

BYPASS FILTER INSTALLATION

Fig. 17-24. Three different oil filtration systems. (Purolator)

flow system. The pump provides oil under pressure. The pressure regulating (relief) valve controls maximum pressure. The one-half to one psi (3.4 to 6.9 kPa) check valve in the filter closes when the engine is stopped, thus preventing the filter from draining. A low-pressure bypass valve shown is sometimes incorporated to bypass the filter completely when it clogs and pressure on the bearing side drops to around 20 lbs. (138 kPa). A more commonly used setup however, is the bypass relief valve that will open at a 15-20 psi (103 to 138 kPa) difference in pressure. When the filter clogs and the pressure on the bearing side drops 15 to 20 lbs. (103 to 138 kPa) lower than that on the pump side, the bypass opens and delivers unfiltered oil directly to the bearings.

As discussed before, when a full-flow filter is clogged, oil delivery to the bearings is not stopped, but flows through the bypass. When the bypass opens, the oil will be unfiltered and may contain chunks of sludge. For this reason, it is vitally important that oil filter elements be changed at regular intervals determined by engine condition, usage, and conditions of operation. A badly clogged filter is pictured in Fig. 17-25.

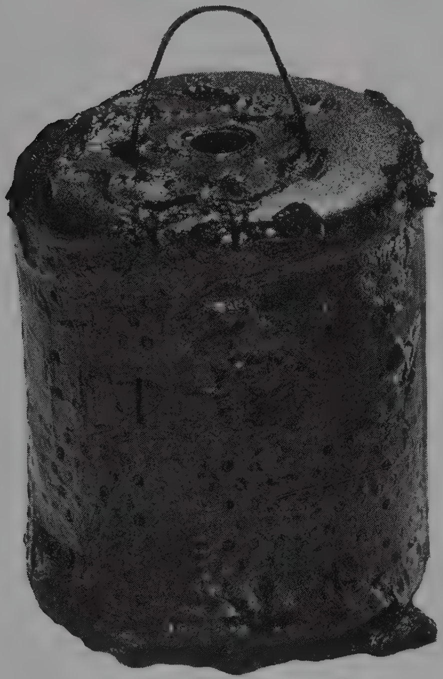


Fig. 17-25. This clogged filter should have been changed long before reaching this state. (Clevite)

FILTERING ELEMENT CONSTRUCTION

Filter elements are SURFACE, DEPTH, and COMBINATION SURFACE-DEPTH types. The surface type utilizes treated paper, folded accordion style, to block the passage of particles. The particles accumulate on the surface of the paper, Fig. 17-26. The depth type uses a number of different fiber products, often wax treated, to remove impurities. The particles penetrate to various depths into the filter material. The combination filter uses a pleated paper with surrounding depth filtering material. See Fig. 17-27.

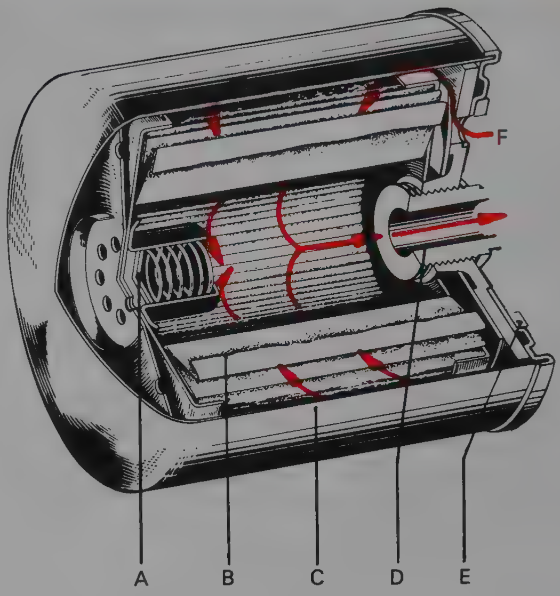


Fig. 17-26. Paper element, surface type filtration filter A—Bypass valve. B—Folded paper element. C—Can or body. D—Outlet fitting. E—Gasket. F—Oil inlet. (Volvo)

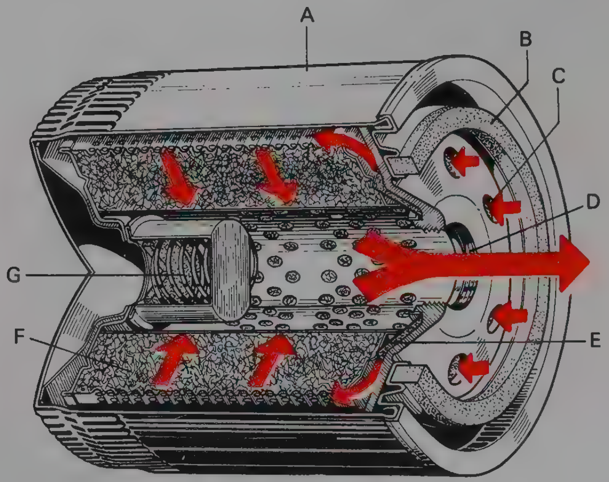


Fig. 17-27. Depth type oil filter. A—Body. B—Gasket. C-Oil inlet. D—Oil outlet. E—Element case. F—Depth filtering element. G—Bypass valve. (Saab)

Remember that even the best filters will not remove all impurities (water, acids, microscopic abrasive particles). In addition, as filters begin to load up (clog), they become less efficient.

CHANGING A CARTRIDGE OR SPIN-ON FULL-FLOW FILTER

Use a suitable wrench to remove the old filter. Fig. 17-28 illustrates a handy wrench for filters without a regular hex head wrench fitting.

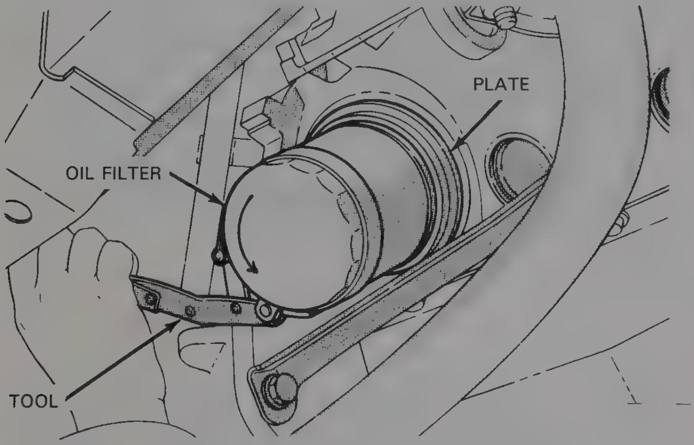


Fig. 17-28. Using a special tool to remove a full-flow, spin-on type oil filter. (Chrysler)

Wipe the engine filter base clean, as shown in A, Fig. 17-29. Rub a thin film of engine oil (not grease) on the new filter seal ring, B, Fig. 17-29. Run the filter up until the seal ring engages the base and then give it about a half turn more, C, Fig. 17-29. In tightening, follow the manufacturer's specifications. Do not overtighten as excessive pressure may split the gasket, distort the filter, and make future removal difficult.

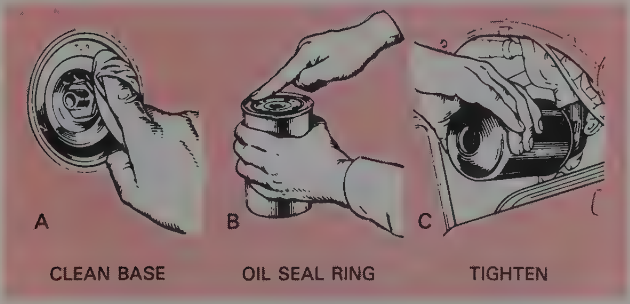


Fig. 17-29. Changing a spin-on oil filter.

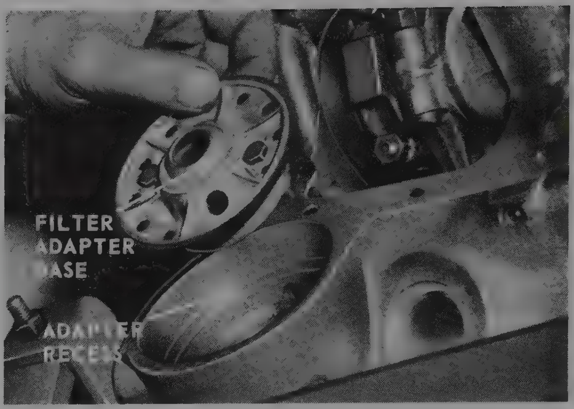


Fig. 17-30. Removing a filter adapter base for cleaning. Recess should be cleaned also. (G.M.C.)

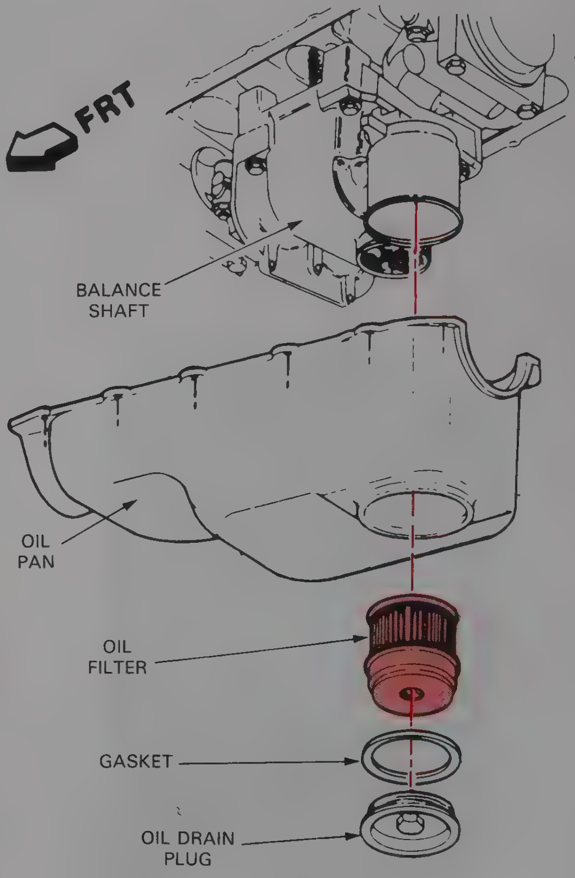


Fig. 17-31. This oil filter is located in the oil pan. (Buick)

On some engines, it is essential that the filter adapter base valve assembly be removed for cleaning prior to installing a new filter. See Fig 17-30. When replacing, make certain the original positioning is retained.

Some full-flow filters use a removable filter element. In such cases, clean the filter housing, center bolt, and related parts. Use NEW gaskets. Lightly oil housing gasket upon assembly. BE SURE THE FILTER ELEMENT IS THE CORRECT LENGTH AND THAT IT FITS THE CENTER BOLT SNUGLY. A filter that is too long will be crushed. One that is too short will not be secured. Some disposable elements are located inside the oil pan. See Fig. 17-31.

CHANGING BYPASS FILTER

Remove and discard the old filter element. If provided, the drain plug may be removed from the filter body or the residual oil may be removed with a sump pump, as in A, Fig. 17-32. Wipe the body clean, B, and insert the new element, C. Install a new gasket, D, in the cover. Oil lightly. Tighten cover, E, securely.

Always check the condition of the hose or lines leading to the bypass filter body. After changing filter, regardless of the type of filter, always start the engine and run at fast idle for several minutes. Check carefully for leaks around the filter. When a filter is changed, it will require adding extra oil to that normally required to fill the crankcase without a filter change.

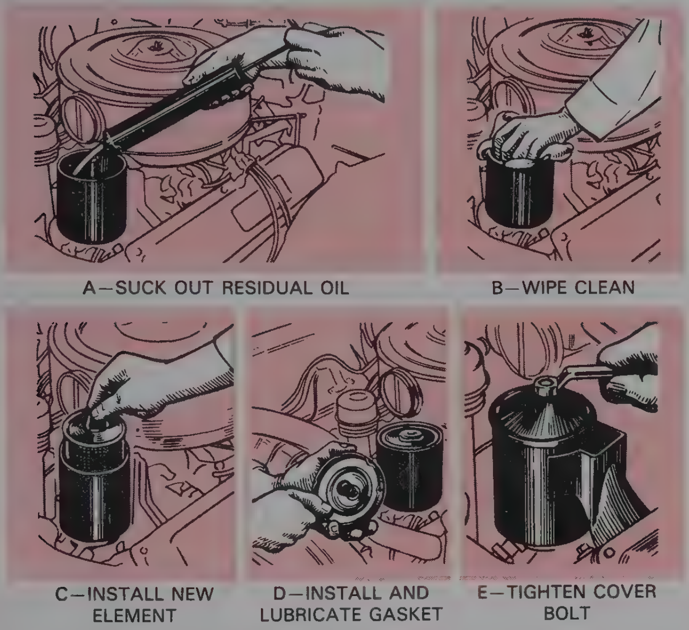


Fig. 17-32. Changing a bypass type filter element.

OIL COOLER

If an engine employs an oil cooler, check lines and fittings for leaks. Replace cracked hoses. Following engine work, cooler system should be thoroughly flushed. Check cooler for presence of dirt, leaves, or other debris that may interfere with the cooling action. One type of engine oil cooler is pictured in Fig. 17-33.

ENGINE OIL CLASSIFICATION—VISCOSITY

Viscosity refers to an oil's resistance to flow. An oil that flows readily is commonly referred to as THIN or LIGHT. One that flows slowly is called THICK or HEAVY.

Engine oils are graded according to their viscosity by SAE (Society of Automotive Engineers) numbers ranging typically from 5W to 50. The rating is determined by an instrument called a VISCOSIMETER.

A specified amount of oil is placed in the viscosimeter and then brought to an exact temperature. It is then allowed to flow through an opening of definite diameter. The time, in seconds, required for the sample to pass through determines the viscosity of the oil. The higher the number (slower flow) the heavier (more viscous) the oil.

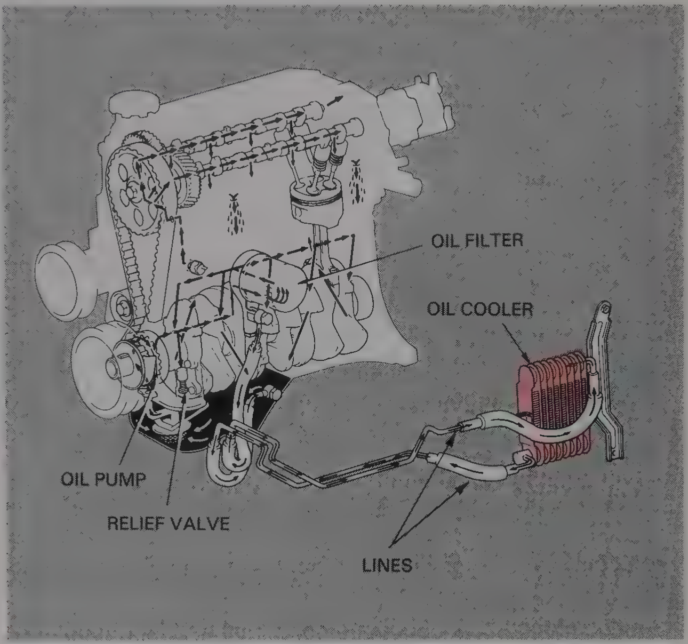


Fig. 17-33. Engine oil cooler. Check lines and fittings for cracks and leaks. (Toyota)

OIL VISCOSITY INDEX RATING

When heated, engine oil tends to become thinner (less viscous). If a specific oil thins out a great amount upon heating, it is said to have a LOW VI (Viscosity Index). If it resists thinning, it will have a HIGH VI. The VI rating is an indication of a given oils ability to resist viscosity changes brought about by heating.

MULTI-VISCOSITY OILS (MULTI-GRADE)

Multi-grade oils meet the viscosity requirements of TWO or more SAE grades. They are marked SAE 5W-20, SAE 5W-30, SAE 10W-20W-30, SAE 10W-30, SAE 10W-40, SAE 10W-20W-40. They are sometimes called all-weather, all-season, or multi-viscosity oils in that they meet the SAE specifications for the high temperature requirements of a heavy oil as well as the low temperature requirements of a light oil. Look at Fig. 17-34.

OIL SERVICE CLASSIFICATION

At the present, there are six basic oils adapted for use in automotive gasoline engines. The API (American Petroleum Institute) has classified these oils as SA, SB,

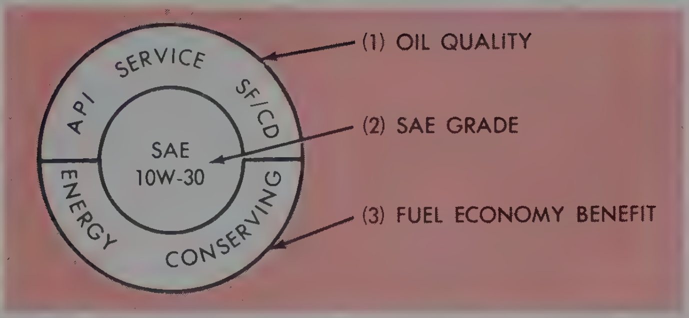


Fig. 17-34. Typical engine oil can markings showing viscosity (10W-30) and service classification (SF/CD). (Chrysler)

SC, SD, SE, SF, and SG.

The letter "S" indicates the oil is basically for Service Station (gasoline engine) use. Commercial and fleet (diesel engines) oils use the letter "C" and are classified as CA, CB, CC, CD, and CE.

SA (Utility Gasoline and Diesel Engine Service) oil is for use in utility engine operation under highly favorable conditions. This oil is recommended for light loads, moderate speeds, and clean conditions. It generally contains no additives.

SB (Minimum Duty Gasoline Engine Service) oil is for gasoline engines operating under mild conditions where little oil compounding (addition of other materials to oil) is required. They will provide resistance to oil oxidation, bearing corrosion, and scuffing (parts scratching each other).

SC (1964 Gasoline Engine Warranty Maintenance Service) oil is similar to that used for service in auto engines manufactured from 1964 through 1967. These oils have additives and offer control of wear, rust, corrosion, and high and low temperature deposits.

SD (1968 Gasoline Engine Warranty Maintenance Service) oil is for service typical of that required for 1968 through 1970 auto and light truck engines. The oil is also applicable to some 1971 and later auto engines when so stated by the auto maker. This oil provides additional protection (as compared with SC) against wear, rust, corrosion, and high and low temperature deposits.

SE (1972 Gasoline Engine Warranty Maintenance Service) oil is specified for 1972 through 1979 car and light truck engines. It provides excellent protection against rust, corrosion, wear, oil oxidization, and high temperature deposits that can cause oil thickening. Obviously, this oil can be used in all engines in which SD or SC is normally recommended.

SF (1980 Gasoline Engine Warranty Service) oil is currently the top ranked oil and is generally specified for 1980 and later car and light truck engines. This oil provides improved anti-wear qualities along with increased oxidation stability and protection against engine deposits, corrosion, and rust. SF oils can be used in all engines where SE, SD, or SC are recommended.

Refer to the chart in Fig. 17-35. Note the relation-

REFERENCE CHART

	NEW API ENGINE SERVICE CLASSIFICATIONS	PREVIOUS API ENGINE SERVICE CLASSIFICATIONS	RELATED DESIGNATIONS MILITARY AND INDUSTRY
GASOLINE ENGINES	SA	ML	Straight Mineral Oil
	SB	MM	Inhibited Oil
	SC	MS (1964)	1964 MS Warranty Approved, M2C101-A
	SD	MS (1968)	1968 MS Warranty Approved, M2C101-B, 6041 (Prior to July, 1970)
	SE	None	1972 Warranty Approved, M2C101-C, 6041-M (July 1970)
	SF	None	1980 Warranty Approved
	SG	None	1987 Warranty Approved
DIESEL ENGINES	CA	DG	MIL-L-2104A
	CB	DM	Supp. 1
	CC	DM	MIL-L-2104B
	CD	DS	MIL-L-45199B, Series 3
	CE		

Fig. 17-35. Latest API Service Classifications. Note relationship of new classifications to those previously used.

ship between the previously used API classifications and the new ones in use today.

Oil for SF service may also be required to pass specific use tests that determine the extent to which the oil prevents engine oxidation, scuffing, rusting, wear, corrosion, thickening, and the formation of varnish and sludge. These laboratory tests are referred to as ENGINE SEQUENCE TESTS. They are sometimes also called "Car Manufacturer's Sequence Tests" or "ASTM Sequence Tests."

Oils may also be classified according to MANUFACTURER'S SPECIFICATIONS (developed by some engine makers) and to MILITARY SPECIFICATIONS (developed by military for oils to be used by them).

DETERMINING WHEN OIL SHOULD BE CHANGED

Car and engine manufacturer's give recommendations of around 2,000 to 7,500 miles (3,200 to 12,000 Km) between oil changes depending upon operating conditions.

There are so many variables such as engine load, short trips, speed, temperature, prolonged idling, and dust that an exact recommendation would be unwise.

The following conditions can be considered near ideal and if the engine is operated under them, the oil change interval can be extended to the maximum recommended by the car manufacturer:

1. The engine is mechanically sound.
2. The engine is operated for reasonably long periods each time it is started.
3. The engine temperature is maintained between 180 and 200°F (82.3-93.3°C) or higher.
4. Carburetion or fuel injection system is properly adjusted.
5. Intake air is properly filtered (clean, undamaged filter).
6. Oil filter is in good condition.
7. Crankcase ventilation system is functioning properly.
8. Engine speeds kept from moderate to reasonably high.
9. Engine operated under clean environmental conditions.
10. Engine is not overloaded, such as when pulling a heavy trailer.

If, however, operating conditions are other than ideal, the change interval will be shortened. In fact, under the worst conditions, such as dust storms, prolonged idling, constant stops and starts, the change interval may have to be as little as 500 to 1000 miles (805 to 1600 Km).

In that most engines are not operated under extreme conditions, it is important to know the general conditions surrounding the use of the engine in question. In this manner, a reasonably accurate determination of the oil change interval can be made. At no time should the manufacturer's recommended maximum interval be extended! Also keep in mind that diesel engine oil change intervals are shorter.

OIL CHANGING

Drain the oil WHEN ENGINE IS AT NORMAL OPERATING TEMPERATURE. Allow to drain completely. Clean drain plug and replace. Use a new gasket if the old gasket has been damaged. Fill crankcase with oil of correct grade and viscosity (as recommended by manufacturer). If filter was changed, add extra oil. Before starting engine, check oil level on dipstick.

Run engine for a few minutes. Stop engine. Check for leaks around drain plug and filter. Recheck oil level.

CAUTION: USE CARE WHILE DRAINING THE OIL AS IT MAY BE HOT ENOUGH TO CAUSE PAINFUL BURNS. AVOID SKIN CONTACT.

CRANKCASE VENTILATION

It is vitally important that crankcase fumes be drawn off by the crankcase ventilation system. A ventilating system working poorly or not at all will permit a rapid buildup of sludge, water, and acids that will shorten the service life of the engine.

ROAD-DRAFT CRANKCASE VENTILATION SYSTEM

For many years manufacturers equipped their cars with what was known as a road-draft system. The for-

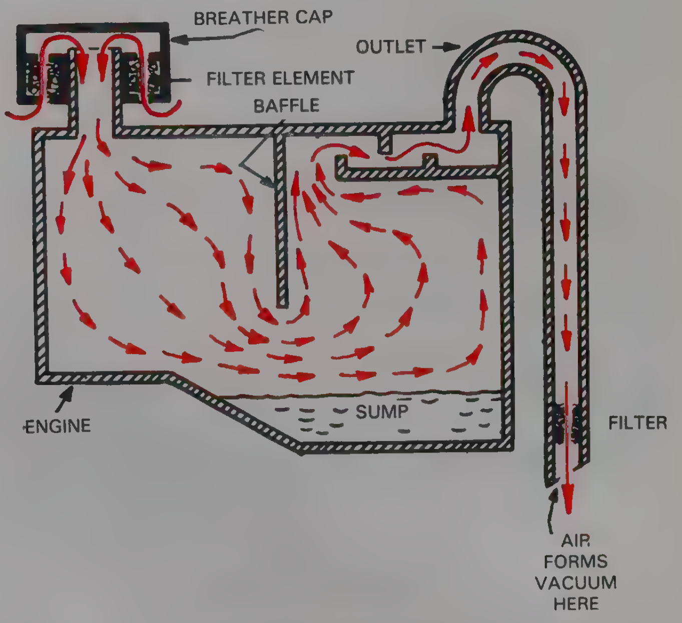


Fig. 17-36. A road-draft engine crankcase ventilation system. All autos now use the positive crankcase ventilation system.

ward movement of the car, aided somewhat by the fan, caused air to flow past the bottom of the road-draft tube. This created a mild vacuum that caused fresh air to enter the breather cap and force the blow-by fumes out through the draft tube. See Fig. 17-36.

The breather, which often served as the oil filler cap, contained an oil dampened metal mesh which filtered the air entering the crankcase. Mesh was often used in the end of the draft tube. For cars using this system, it is important that, at each oil change, the breather cap be washed in solvent, dried, and reoiled. The draft-tube mesh should also be cleaned and oiled.

POSITIVE CRANKCASE VENTILATION (PCV)

Under ideal conditions, the road-draft system did only a FAIR job of removing fumes. It did, however, tend to pollute the surrounding air. In large metropolitan areas, the crankcase emissions, coupled with exhaust fumes and industrial pollution, created a serious "smog" problem.

This prompted development of the positive crankcase ventilation (PCV) system. Early systems employed the OPEN type. Current practice uses the CLOSED system.

For complete details on the construction, operation, and service of the PCV (positive crankcase ventilation) system, refer to Chapter 35, Exhaust and Emission Control Service.

OIL PAN

Whenever the oil pan is removed, clean it thoroughly. When installing pan, use new gaskets and cement or a suitable sealer. When using gaskets or sealer, pay particular attention to the corner areas, which are prone to leak.

The engine in Fig. 17-37 has clean pan contact surfaces. The pan is coated with sealer and is ready to be fastened to the block.

ROTARY ENGINE LUBRICATION

Although quite similar in principle to the system employed on the reciprocating piston engine, some rotary engines use an oil metering pump. This pump, a separate unit from the main oil pump, is used to feed a carefully metered amount of oil to the carburetor. This provides rotor lubrication. Study the rotary engine lubrication system schematic in Fig. 17-38. Note use of metering pump. This system also employs an electric oil level sensor and an oil cooler.

SUMMARY

Engine oil must be of the correct grade and viscosity, and supplied to all moving surfaces in ample quantities.

Oil pickup tubes may be of the floating type or the fixed type. Pickup depth must be checked. Pickup and screens must be cleaned.

Oil pumps are of two principal types: GEAR and ROTOR.

When dismantling the pump, mark gears or rotors so they may be installed in the original relationship to each other and to the pump body. Check end clearance, side clearance, clearance between the gear teeth or the rotor tips. Check for scoring, chipped spots, and other problems. Use new gaskets or O-rings. Clean and lubricate before assembling.

Prime pump with oil before installing. If ignition is

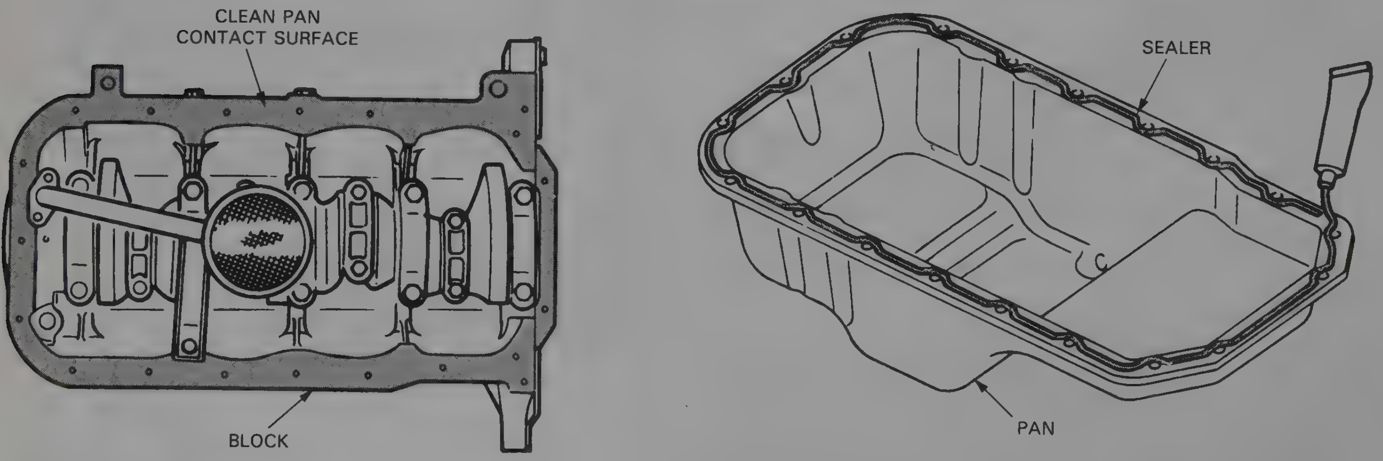


Fig. 17-37. Be careful when installing oil pan gaskets and/or sealer. This setup is ready for pan installation. Align carefully on initial contact to help prevent leaks. (Mazda)

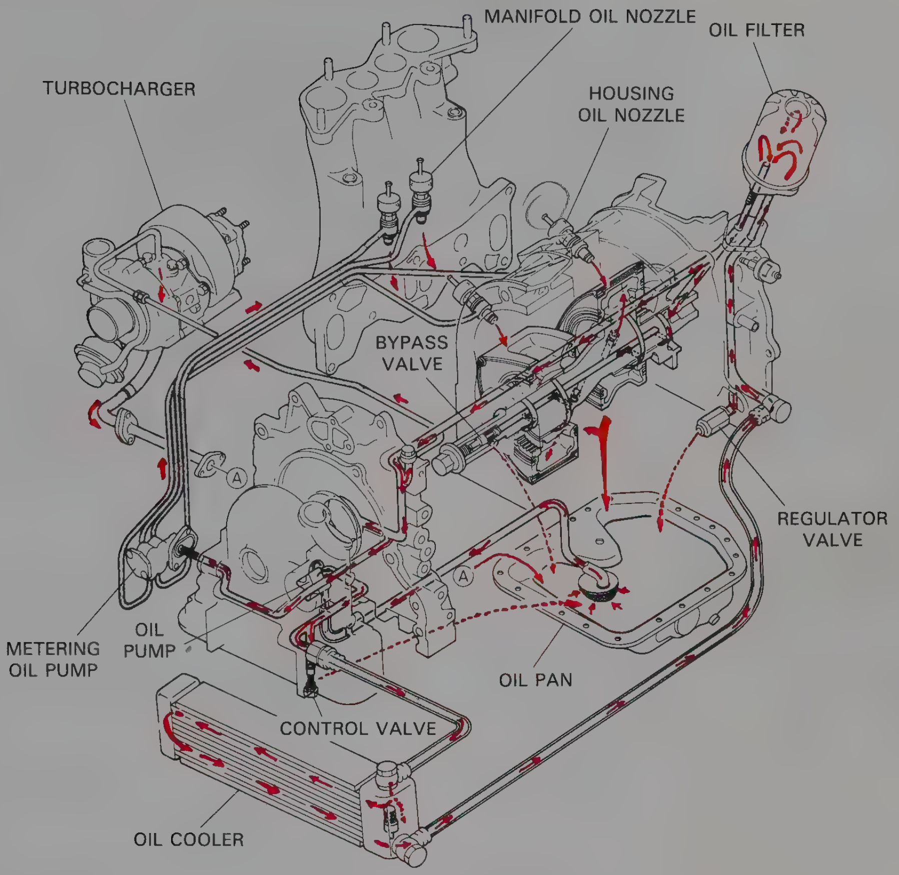


Fig. 17-38. Rotary engine lubrication system schematic. Note oil nozzles, metering pump, and the turbocharger. (Mazda)

affected, check timing when installing pump.

THE ENTIRE SYSTEM SHOULD BE PRIMED BY PRESSURE CHARGING BEFORE THE INITIAL START.

The pressure relief valve must be clean and free of scoring and rust. The valve spring must have the correct tension. Do not alter the spring length.

Clean and rod out oil galleries. Flush with cleaner and blow dry.

Three oil filtration systems are the FULL-FLOW, SHUNT, and BYPASS.

Filter elements are of the DEPTH type, SURFACE CLEANING type, or a combination of the two. Filters should be changed before clogging. Replacement intervals vary with engine wear, use, and driving conditions.

Replacement filters must be of the correct size and type for the engine. Clean housing (if a replaceable element type is used), center bolt and related parts. Use new gaskets. Clean filter base and oil filter housing to base gasket. Tighten as specified. Run engine and check for leaks.

Motor oil, as specified by the manufacturer, should be used.

SF oil is generally recommended for all late model auto engines. It will provide the type of lubrication needed by the modern engine—highly stressed and operating at high temperatures. The use of quality oils, of the correct viscosity, changed at regular intervals, is a must.

At each oil change, the PCV system operation should be checked. Clean or replace valve once a year or every 12,000 miles (19 300 Km) or when an inspection reveals replacement is necessary.

An inoperative PCV system can cause rough idle, rolling, oil film in the engine compartment, heavy sludging, rapid wear, poor mileage, and stalling.

KNOW THESE TERMS

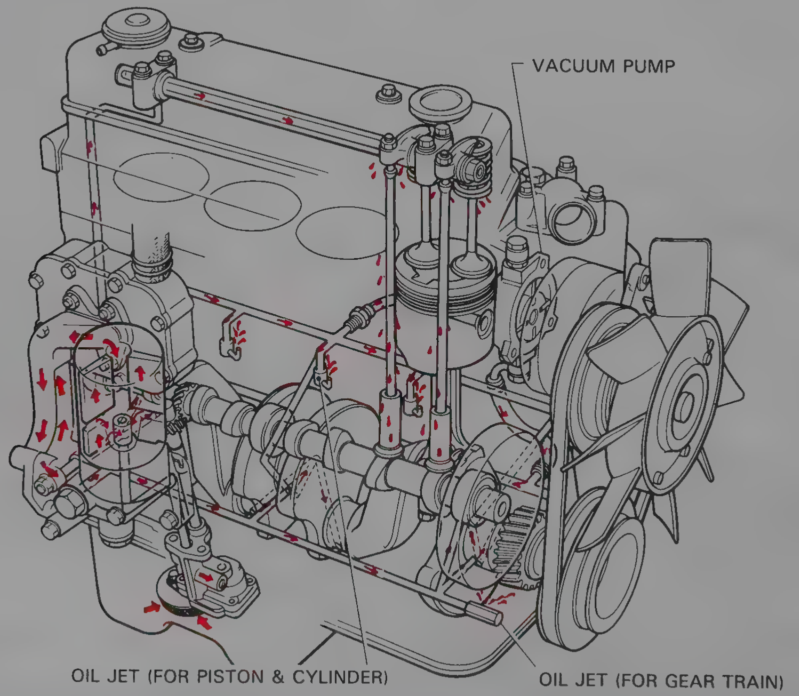
Pickup, Gear pump, Rotor pump, Relief valve, Distribution passage, Depth type filter, Surface type filter, Spin-on filter, Bypass filter, Full-flow lubrication system, Viscosity, API, Service classification, Viscosity rating, Multi-grade oil, Crankcase ventilation, SAE, Bypass valve, Drain plug, Pan, Oil baffle, Backlash, Shunt lubrication system, Engine sequence tests, Sludge.

QUIZ - Chapter 17

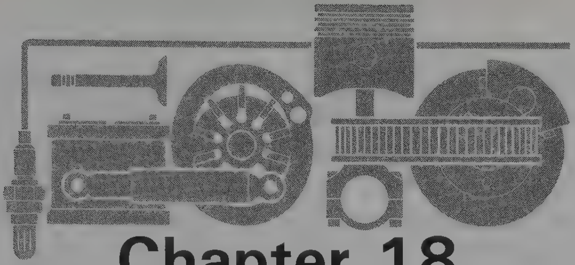
1. Oil VISCOSITY refers to:
   a. Color.

[✓ b.] Flow rate or resistance to flow.
c. Quality.
d. Amount of additives.

2. Most oil pumps are of the plunger type. True or [✓ False?]
3. Oil pickup screens will plug after thousands of miles, the screens should be clean during every overhaul.
4. Despite the fact that they are pumping oil, oil pumps will eventually wear out. [✓ True] or False?
5. Removal of some oil pumps will throw the ignition timin.
6. Both gears and rotors should be align and mark before removal.
7. A gear oil pump should be checked for clearance between the teeth and the pump, body between the gear teeth and for backlash between the gears and the housing cover.
8. A rotor type oil pump should be checked for clearance between the outer rotor and the pump body, between inner and outer rotors and for backlash between both rotors and housing cover.
9. Pump clearances can be quickly checked by using a feeler gauge.
10. The pressure relief valve controls the Maximum amount oil pressure in the system.
11. Never __________ the pressure relief valve spring.
12. The most commonly used type of oil filtration system is:
    a. Shunt.
    b. Bypass.
    c. Splash.
    [✓ d.] Full-flow.
13. The full-flow system filter oil the oil before it reaches the __________.
14. When the filter in a full-flow system clogs up, the oil:
    a. Cannot reach the bearings.
    b. Is shunted into the pan.
    c. Is bypassed directly to the bearings.
    d. Forces a hole through the filter element.
15. A depth filter stops all the dirt on the surface of the element. True or False?
16. A spin-on filter should be tightened about:
    a. Two full turns after contacting the base.
    [✓ b.] One-half to three-fourths turn after contacting the base.
    c. To 60 ft.-lbs. (81 N·m).
    d. Only until the gasket contacts the base.
17. On a bypass system, it is important to clean the filter [illegible].
18. Changing the filter requires the addition of [illegible] [illegible] of oil to the normal crankcase fill.
19. Drain the oil when the engine is __________.
20. The six gasoline engine service classifications for oil are __________, __________, __________, __________, __________, __________.
21. Explain the meaning of each oil service classification.
22. Positive crankcase ventilation systems are of two types, the Open and the Closed.
23. What happens when the engine ventilation system is not functioning?



Lubrication diagram for an in-line, four-cylinder diesel engine. (Nissan)



Chapter 18

ENGINE ASSEMBLY, INSTALLATION, BREAK-IN

After studying this chapter, you will be able to:

☐ Summarize a typical sequence for assembling an engine.

☐ Describe how to install an engine in a car.

☐ Pressurize the engine lubrication system with oil.

☐ Make final checks before starting the engine.

☐ Operate an engine properly for safe break-in.

In assembly of engine components (parts), no single method is right every time. Mechanic preference, engine peculiarities, and part availability all help to determine the order of assembly for any given engine.

The following sequence of assembly is typical for most engines and may be used as a general guide. It is important, however, that the mechanic study the construction of each specific engine and the manufacturer's shop manual, if available. This advance planning will help the mechanic to anticipate and prevent any problems caused by assembling the parts in the wrong sequence.

For example, suppose you are working on an engine with mushroom type valve lifters. If you installed the camshaft, crankshaft, and timing chain and are planning to insert the lifters from the top of the bore (as is almost always done), you would find that mushroom lifters require installation BEFORE the camshaft.

Assume that you are working on an engine with push rod operated valves and that you have installed all the rocker arm assemblies BEFORE inserting the push rods. On some engines you could very well be forced to remove all the rocker arms in order to install the push rods.

In both of these instances, as a result of your failure to study the engine construction and to "think ahead," you would have to waste valuable time disassembling some parts to permit installation of others.

TYPICAL SEQUENCE OF ASSEMBLY

The sequence or order of assembly described in this chapter covers MAJOR units. It will be assumed that subassemblies such as valves, springs, bearings, and rings have been correctly installed. It is further assumed that all parts have been cleaned, checked, lubricated, and replaced or repaired as needed.

ANY PARTICULAR STEP IN THIS ORDER MAY BE REVIEWED IN DETAIL BY REFERRING TO THE CHAPTER COVERING THE OPERATION OR PART CONCERNED.

Mount the engine block in a suitable stand and install:

1. Block oil gallery and core hole plugs.
2. Crankshaft.
3. Camshaft (if valve lifters are mushroom type, install them first; if camshaft timing gear is pressed on, make sure it is installed before camshaft).
4. Timing gears, timing chain, and sprockets (make certain timing marks are aligned). On overhead camshaft designs, timing chain, gear, or belt installation must be delayed until cylinder head is installed.
5. Piston and rod asemblies.
6. Oil pump, oil pickup, and connecting lines where used.
7. Timing chain, gear, or belt cover.
8. Vibration damper and pulleys.
9. Oil pan.
10. Head(s).
11. Water pump.
12. Valve lifters, push rods, and rocker arm assemblies.
13. Set valve clearance at this time.
14. Intake manifold.
15. Exhaust manifold(s).
16. Distributor (make certain timing is correct), plugs, coil, wiring, fuel pump, carburetor, fuel or vacuum lines, generator (alternator), starter, water temperature, and oil pressure senders, etc.
17. Drive belts.
18. Flywheel (on standard transmission models, clutch disc, pressure plate, and clutch or flywheel housing can be installed at this time).

19. Transmission (in some cases, it is possible and desirable to attach the transmission to engine and install as a single unit; on others, such a method is not feasible).

DO NOT HURRY!

Student mechanics often become excited as the time draws near to start the engine. This is as it should be, as your knowledge, care, and skill will receive the "acid test" when the engine is started.

It is at this point that many fine overhaul jobs have been ruined by carelessness brought about by hurrying. Work energetically, of course, but work carefully—THINK and avoid a "last minute rush!"

COVER WHEN NOT WORKING

When not actively working on the engine, it is advisable to cover it with a protective cloth. When the heads and the intake manifold are installed, install the plugs and cap off the manifold to prevent the entry of dirt or small parts.

ENGINE INSTALLATION

Attach a lift strap or fixture. IMPORTANT: STUDY CHAPTER 12 FOR RECOMMENDATIONS ON ATTACHING LIFT DEVICES. PAY PARTICULAR ATTENTION TO THE SAFETY RULES FOR PULLING. THEY APPLY TO INSTALLATION ALSO.

Place protective pads on fenders. Raise engine with a suitable hoist being careful to balance the engine at the angle desired. Look at Fig. 8-1.

INSTALLATION—TRANSMISSION IN CAR

Guide the engine down into the engine compartment and back to engage the transmission. Engine crankshaft and transmission input shaft centerlines must be at the same level and parallel with each other. For manual shift transmissions, make certain the transmission input shaft passes through the throwout bearing, through the clutch disc, and into the crankshaft pilot bearing (see Chapter 24, on clutch service for full details). For automatic transmissions, start the converter pilot into the crankshaft. Be careful not to bend the relatively light flex-type flywheel or drive plate. Remove the converter restraining strap.

Install the clutch or converter housing to engine fasteners. On automatics, install converter to flywheel fasteners. Torque engine mount bolts.

INSTALLATION—TRANSMISSION ON BENCH

Guide the engine into place on the front mounts. Install the mount bolts loosely. Use a strap to support the rear of the engine. Then, remove the engine lift or hoist.

Raise the car and install the transmission. Attach the engine rear mount cross member and tighten the engine mounts. Remove the support strap. Torque all mount bolts to factory specifications.

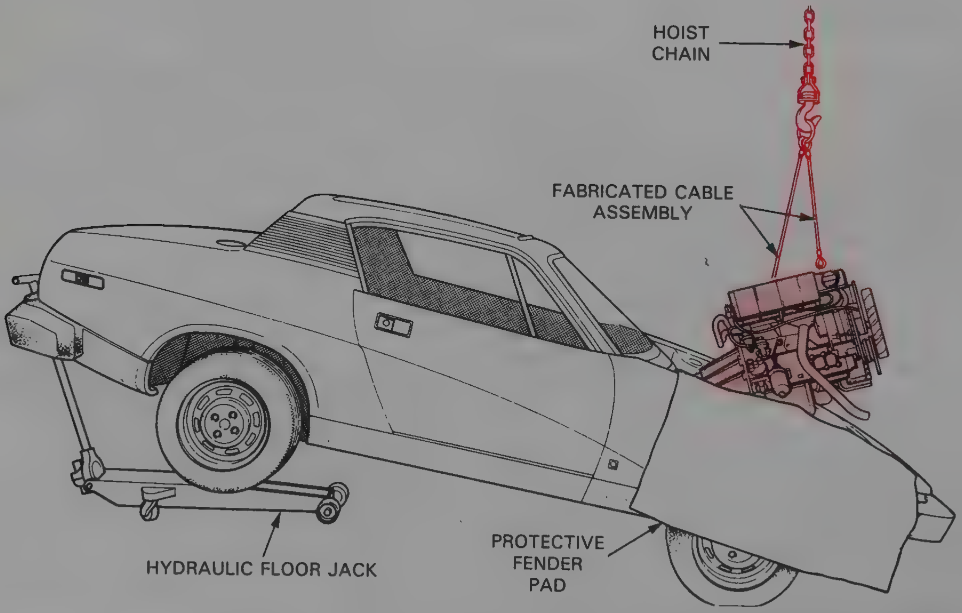


Fig. 18-1. Use great care when removing or installing an engine. Make certain hoist or lift is securely attached. On this setup, rear of car has been elevated to assist in installation. (British-Leyland)

INSTALLATION—TRANSMISSION ON ENGINE

This arrangement requires care and skillful maneuvering because the engine and transmission form a long unit. The engine will usually have to be tipped at a steep angle (up to 45 deg.). Guide engine into place. Position transmission with a jack, using a wood block to prevent damage to the transmission pan. Install rear support cross member and attach to engine rear mount. Install and torque all mount bolts. Remove jack and attach drive shaft (see Chapter 27 on drive line service).

USE CARE

When installing the engine, lower it slowly and carefully. Avoid damage to the car body or to underhood accesories. Inspect as the lowering progresses to make sure the engine is not catching on some unit. Gentle shaking, pressure with a pry bar, and judicious use of a jack are all helpful in engine positioning. If difficulty is encountered, do not try to use "brute force." Find out what is causing the trouble and remedy it so the engine will position without undue forcing. Make certain the mounts are properly assembled and torqued. Fig. 18-2 illustrates a typical three-point engine suspension setup.

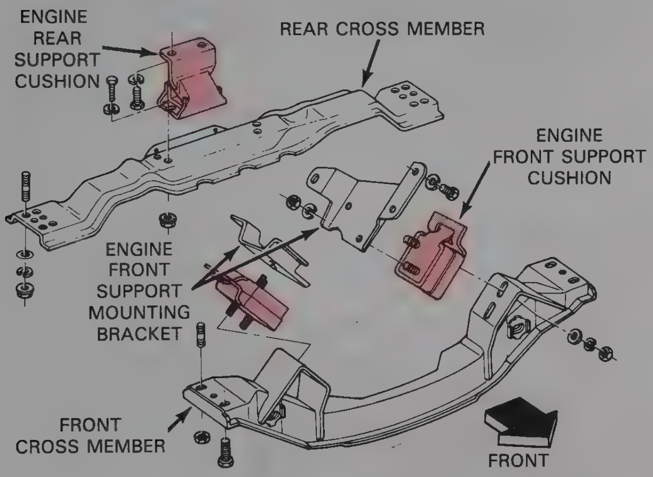

ENGINE REAR SUPPORT CUSHION
REAR CROSS MEMBER
ENGINE FRONT SUPPORT CUSHION
ENGINE FRONT SUPPORT MOUNTING BRACKET
FRONT CROSS MEMBER
FRONT

Fig. 18-2. Three-point suspension engine mount setup. (American Motors)

CONNECT ALL WIRING, HOSE, TUBING, AND LINKAGE

If the car has an automatic transmission oil cooler, connect the lines. Connect all fuel and vacuum lines. Connect radiator hoses. Attach all wiring. Attach transmission shift linkage and throttle linkage. Connect power steering and air conditioning lines. Check each unit to make sure it is properly connected. Polarize generators but do NOT polarize alternators! Connect exhaust system.

MARKING PAYS OFF

As mentioned in the chapter on engine removal, all wires, lines, and hoses should be clearly marked so they may be reinstalled in a minimum amount of time. If you marked the various items properly when they were removed, you will now appreciate the importance of careful marking.

OVERHAULED ENGINE NEEDS INSTANT LUBRICATION

When an overhauled engine is started, it is vitally important that ALL MOVING PARTS RECEIVE ADEQUATE LUBRICATION.

Even though all parts may have been thoroughly lubricated upon assembly, most of this oil will have drained off into the pan. The oil galleries are dry, the filter is dry, and the tappets (hydraulic) will need additional oil.

Upon starting, the oil pump must prime itself. It must then force oil throughout the system to fill the galleries, filter, and other areas before any oil will find its way to the bearings. THIS TAKES TIME.

Do not be fooled by the oil pressure gauge registering immediate pressure. This could be AIR in the lines.

Remember that during this critical period of time, the engine is operating without proper lubrication. New parts are closely fitted and areas such as cylinder, ring, and piston surfaces will quickly heat up and cause scoring and scuffing. Bearing and journals can also be damaged by the lack of oil upon starting (dry start).

This can be prevented by pressurizing the lubrication system before starting the engine.

PRESSURIZING ENGINE LUBRICATION SYSTEM

The system may be pressurized by using a special tank and hose setup as pictured in Fig. 18-3.

The tank is filled to the indicated level with the

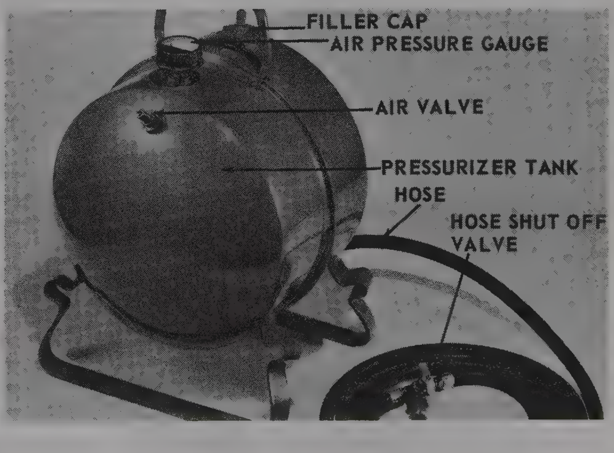


Fig. 18-3. Typical lubrication system pressurizer. (Clevite)

SAME KIND OF OIL THAT WILL BE USED IN THE ENGINE.

Air pressure up to the normal system pressure (around 40 lbs. psi or 276 kPa) is then admitted to the tank. Watch gauge to avoid excess pressure.

The hose fitting is attached to some external entry point into the lubrication system—such as the oil sender hole. The valve is opened and oil under pressure flows through the system. This primes the oil pump and fills the galleries, filter, lifters, and bearings. This assures prompt lubrication upon starting. Rotate the engine several times while pressurizing, Fig. 18-4.

PRESSURIZER AS A BEARING LEAK DETECTOR

The pressurizer (often referred to as a bearing leak detector) can also be used to check bearing clearance. Some mechanics prefer to pressurize the lubrication system before installing the pan. This technique permits watching the leakage rate at the ends of the bearings. The oil should pass through each bearing and fall in a series of individual drops. A STEADY STREAM indicates EXCESSIVE CLEARANCE. When a steady stream is found, turn the crankshaft one-half revolution in case registration (alignment) of oil holes is responsible. NO OIL or LESS THAN AROUND 20-25 DROPS PER MINUTE indicates INSUFFICIENT CLEARANCE, Fig. 18-5.

Engines that have been in storage for a length of time should be pressurized upon installation even though this may have been done upon completion of the overhaul.

FILL WITH OIL

Bring the oil level in the pan up to the full mark. Do not overfill. Use a top quality oil of the type and viscosity recommended by the manufacturer. Prestart

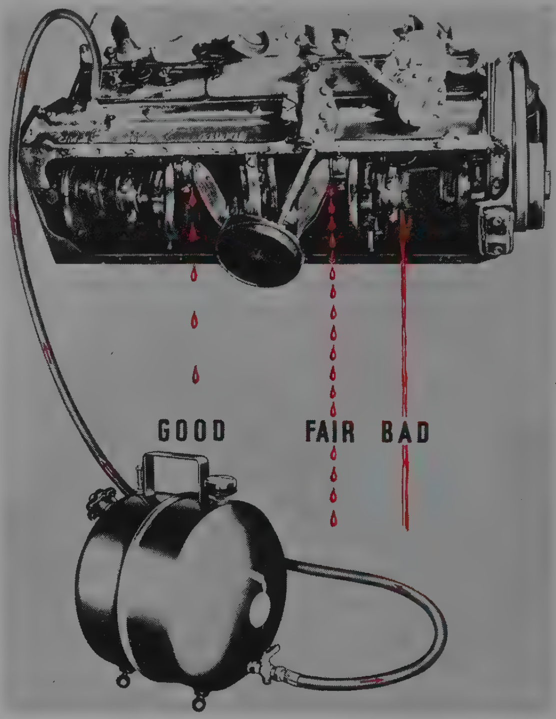


Fig. 18-5. Amount of run-off from bearings gives an indication of clearance. (Sealed Power)

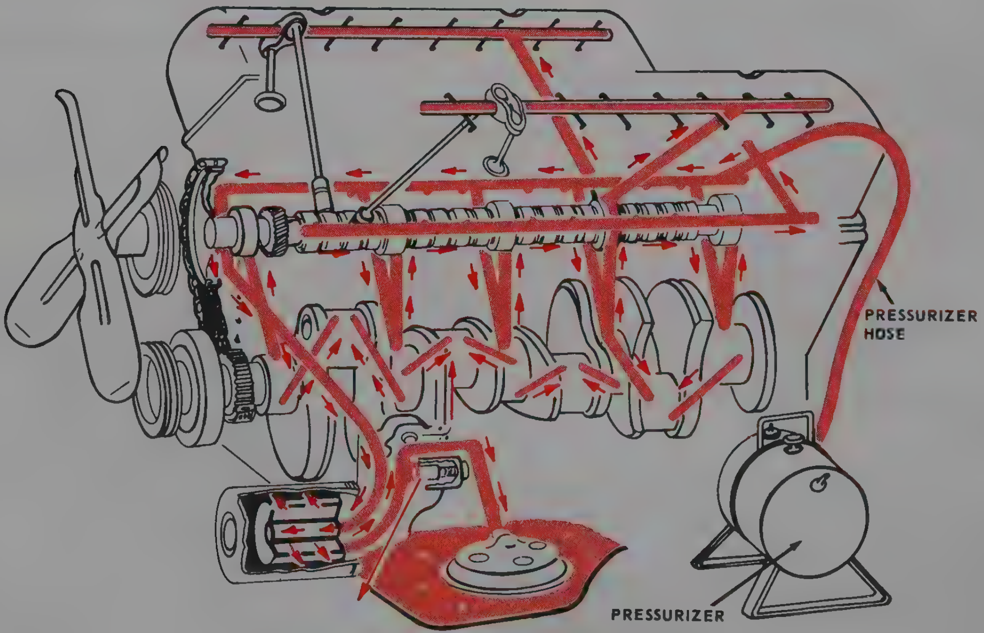


Fig. 18-4. Pressurizing lubrication system. Arrows indicate flow of oil from pressurizer through system. (Hastings)

pressurizing eliminates adding an additional quart for the filter.

FILL THE COOLING SYSTEM

Fill the radiator to the full mark (do not overfill) with factory recommended mixture of clean, soft water and ethylene glycol (antifreeze) solution to provide water pump seal lubrication, resistance to leaks, and protection from rust and corrosion.

If water alone is used, be certain to add a good rust inhibitor. Many car makers insist on addition of ethylene glycol. Failure to add antifreeze could void warranty. Also, air conditioned cars may require antifreeze protection to prevent overheating.

CHECK GAS TANK

Check gasoline level, and if needed, add gasoline to the tank. If the vehicle has been laid up for an extended period of time, it is a good idea to drain the tank and refill with fresh gasoline. If the tank is to be drained, refer to Chapter 20 on fuel systems for necessary safety precautions.

CHECK BATTERY

Check, and if needed, add distilled water to bring the battery electrolyte up to the proper level. The battery should be in good condition and fully charged. Install the battery and connect battery cables.

BEFORE STARTING

Before starting the engine, it is wise to double check the following items:

1. Oil level in the pan.
2. Coolant level in the radiator.
3. Spark plug wire installation order.
4. Ignition point gap or reluctor-to-armature air gap.
5. Ignition timing.
6. Valve clearance.
7. Carburetor automatic choke and idle valve adjustment.
8. Position of transmission shifter.

Remove tools, extension cords, and wiping cloths from the engine compartment. Have a fire extinguisher handy for use in case of emergency, and know how to use it.

STARTING ENGINE

A properly overhauled engine should start readily but it may have to be cranked for a short time to allow the fuel pump to fill the carburetor. Carburetors on cars equipped with electric pumps will fill without cranking.

Some mechanics fill the carburetor with a gravity feed can, or by using an electric pump to force gas from a container into the carburetor. This helps to eliminate excessive cranking.

Make certain the automatic choke has closed the choke valve. Do not place the palm of your hand over the carburetor air horn to choke the engine while cranking. A backfire through the carburetor could inflict a serious burn.

If the engine cranks slowly, because of an old battery or a poor starter motor, a booster battery may be used to facilitate starting. Hook the booster to the car battery in PARALLEL—positive to positive and negative to negative. NEVER HOOK A BOOSTER BATTERY IN SERIES. A series hookup doubles battery voltage and can cause extensive damage to the electrical system. See Chapter 22 on battery service for details on the use of booster batteries.

PROPER BREAK-IN IS IMPORTANT

Modern design, materials, machinery, and repair procedures make it possible to assemble an engine with highly accurate clearances and controlled finishes. This has eliminated the long, old-fashioned break-in period. However, despite the fact that break-in is simplified, proper break-in is still of major importance. The first hour or so of engine operation is extremely critical. Lubrication, rpm, temperature, and loading are all vital. If these are correct, they will produce proper wearing in of the rings, cylinder walls, and bearings until mating parts are smooth enough to provide proper sealing and to reduce friction to a normal level.

Failure to follow accepted break-in rules may result in extensive engine damage from scuffing and scoring. The amount of damage is often hard to determine immediately, but the engine may fail in service thousands of miles sooner than would be normally expected.

FAST IDLE UNTIL NORMAL TEMPERATURE IS REACHED

As soon as the engine is started, set the idle speed adjustment screw to produce an engine speed of around 1,200 rpm. This will insure a good oil pressure and throw-off will be sufficient to adequately lubricate the cylinder walls. Operate the engine at this speed until normal operating temperature is reached (usually 15 to 20 minutes).

If for some reason it was not possible to pressurize the lubrication system before starting the engine, a few squirts of engine oil should be directed into the carburetor air horn during the first minute or two of operation. This will provide cylinder lubrication until bearing throw-off and "spit hole" lubrication takes over.

Check oil pressure and coolant temperature occasionally during the warmup. Check coolant level as there may have been air in the system when filling. Inspect for any signs of fuel, oil, or coolant leakage.

ADEQUATE VENTILATION

NEVER RUN A CAR IN A CLOSED AREA. OPEN PLENTY OF WINDOWS AND DOORS AND IF THE WEATHER PERMITS, RUN THE CAR OUTSIDE. IF SPECIAL EXHAUST DISPOSAL PIPES ARE AVAILABLE, RUN THE EXHAUST INTO THESE LINES. REMEMBER THAT CARBON MONOXIDE IS A DEADLY POISON AND THAT IT IS CUMULATIVE. If you are exposed to exhaust fumes every day, even in relatively small amounts, it will build up in your system until you become physically ill. ALWAYS AVOID ALL POSSIBLE EXPOSURE TO EXHAUST FUMES.

RETORQUE AND MAKE FINAL ADJUSTMENTS

When normal temperature is reached, turn the engine off and retorque the heads and manifolds. Give the valve clearance a final adjustment, if required. See Fig. 18-6. If setting mechanical lifter clearance, use hot setting recommendations. Start and run the engine long enough to check the ignition timing and set the carburetor idle valve adjustment to produce smooth idle.

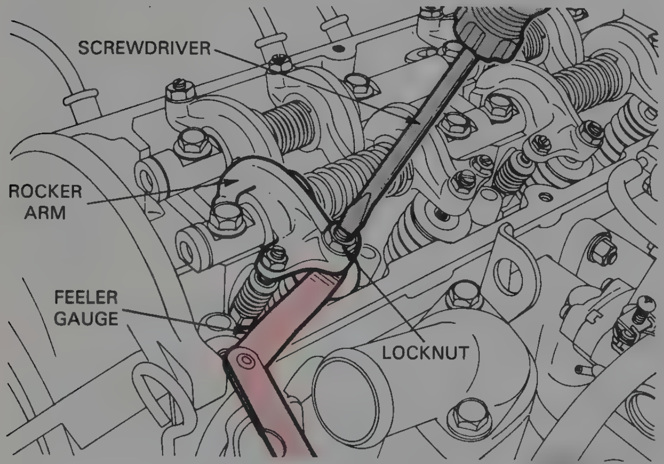


Fig. 18-6. Following initial break-in, it is a wise procedure to recheck valve clearance on engines that do not employ self-adjusting valve mechanisms. Note that water hose has been removed to simplify illustration. (Chrysler)

Set the idle speed screw so the idle will be a trifle faster than normal. This will insure better cylinder lubrication during idling. Explain the fast setting to the owner and inform him or her that the idle should be returned to normal at the end of the first 500 miles (805 km).

ROAD TEST AND BREAK-IN RUN

Drive the vehicle to a spot where you can SAFELY reach a speed of 50 mph (80 km/h). Accelerate rapidly up to about 50 mph (80 km/h). Immediately let up on the accelerator and allow the car to coast down to around 30 mph (48 km/h). Drive at 30 mph (48 km/h) for a block or so and again accelerate rapidly up to 50 mph (80 km/h). Once again, coast back to 30 mph (48 km/h). Repeat this procedure fifteen to twenty times. When slowing down, watch for cars behind you.

The object of the acceleration is to increase ring loading against the cylinder walls and thus speed up break-in. During the coast period, heavy vacuum in the cylinders will draw additional oil up around the rings.

Devote as much time as practical for the break-in run. The fifteen to twenty acceleration-coast cycles mentioned are MINIMUM requirements.

Observe oil pressure, temperature, steering, braking, engine performance, and shifting during the run. When back at the garage, check again for any possible leakage.

DYNAMOMETER BREAK-IN

It is possible to mount an engine in a dynamometer for break-in, as shown in Fig. 18-7.

DYNAMOMETER ENGINE BREAK-IN PROCEDURE

STEP	TIME	MANIFOLD VACUUM IN INCHES OF MERCURY	RPM
1	Warm up period of 10 minutes	No Load	800
2	10 minutes	15 inches	1500
3	15 minutes	10 inches	2000
4	15 minutes	10 inches	2500
5	15 minutes	6 inches	3000
6	5 minutes	Open throttle (Full Load)	3000

NOTE: Engine should be started and brought to operating temperature as though in the car. Following retorquing, valve clearance and timing checks, etc., proceed to Step 1.

Fig. 18-7. Dynamometer engine break-in procedure. (Perfect Circle)

OWNER SHOULD BE CAUTIONED

Following the initial break-in, final checks, and vehicle cleanup, the car is ready for delivery. Be sure to caution the owner to avoid sustained high speed driving and heavy loads during the first critical 200 to 300 miles (320 to 480 km). Ask the owner to bring the car in at the end of the first 500 miles (805 km) for an oil change and a checkup. Inform the owner that oil consumption may be noticeable until the rings are seated.

During break-in, metal particles will be dislodged and enter the oil. Changing the oil and the filter at the end of the first 500 miles (805 km) eliminates the possibility of engine damage by the prolonged use of contaminated oil. At the time of the oil change be sure to check for leaks. Ask the owner how the car has been performing.

RING SEATING TAKES TIME

The overhauled engine may continue to burn oil for a short while. Oil consumption should drop to an accepted norm by the end of 2,500 miles (4 025 km) or around 65 hours of operation. Remember that a normal amount of oil consumption varies with engine condition, design, vehicle use, operating conditions, and driving habits. A general rule of thumb is to consider EXCESSIVE oil consumption a condition in which a quart of oil is consumed in less than 700 miles (1 127 km). One quart per 1500 miles (2 415 km) may be considered good oil mileage. These are approximations and are for normal driving.

ENGINE NEEDS HELP

While an engine may be in good mechanical condition, the ignition, fuel, and cooling systems must be functioning properly or engine performance will be substandard.

Protect your work and your reputation by encouraging the owner to have essential work performed in these areas. Point out why it is important, and what can be expected if the work is NOT done. It is a good idea to put the suggestions in writing, so the owner will not later say, "I certainly wish that mechanic would have told me this work was needed."

SUMMARY

Engine component order of assembly varies. Study the engine construction and "think ahead." Do not rush the assembly work. Proceed carefully.

Follow safety rules when installing the engine. If a manufacturer's shop manual is available, use it for assistance in installation. Lower the engine into place slowly and avoid damage to car or accessory units.

Attach all wiring, hose, and tubing. Connect transmission, clutch, and accelerator linkage. Torque engine mounts and adjust belts.

Pressurize lubrication system before starting the engine.

Bring oil level up to the full mark. Fill radiator. Check battery or charge. Clear away tools, cords, and cloths. Have a fire extinguisher ready.

Avoid priming with raw gas in the carburetor air horn. Never use your hand for a choke. Upon starting, run engine at about 1200 rpm until hot. Check for leaks, oil pressure, and coolant temperature while running. When hot, shut off and retorque heads and manifolds.

Drive the car full throttle up to 50 mph (80 km/h) and then coast to 30 mph (48 km/h). Repeat this procedure fifteen to twenty times. The engine may be run in on a dynamometer if available.

Instruct owner as to importance of proper operation during the first 150 miles (242 km), a 500-mile (805 km) oil change, and taking care of any needed adjustments or repairs in the cooling, fuel, and ignition systems.

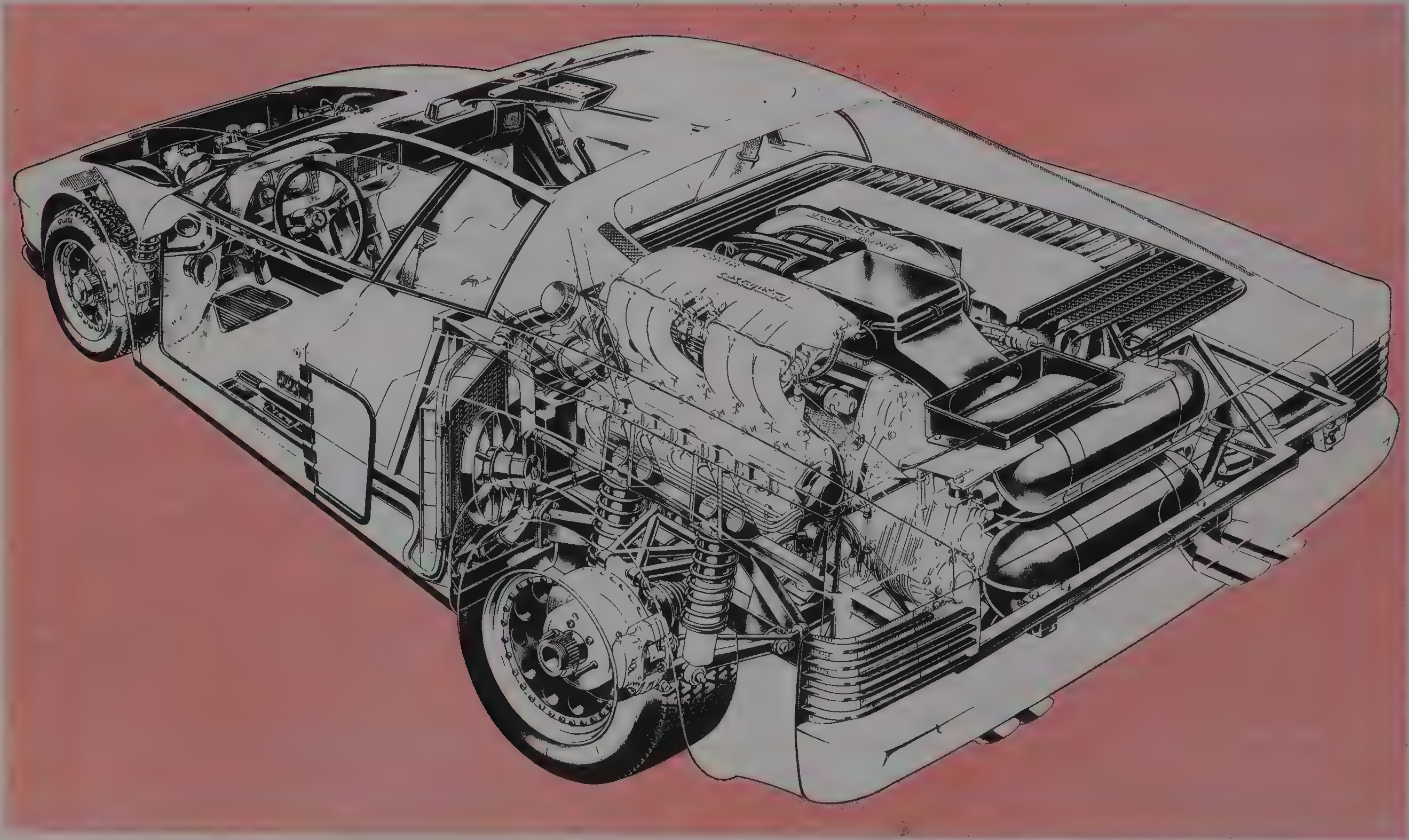
KNOW THESE TERMS

Break-in, Sequence of assembly, Lift strap, Hoist, Pressurizing lubrication system, Scuffing, Scoring, Booster battery, Retorque, Road test, Dynamometer break-in, Idle speed screw, Fast idle, Burn oil, Fender pad.

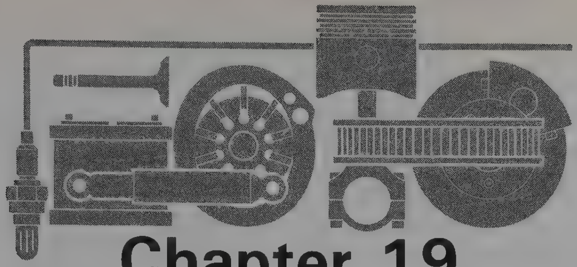
QUIZ - Chapter 18

1. There is an exact order of assembly that applies to all engines. True or False?
2. List eight rules of safety regarding engine pulling and installation.
3. When installing the engine, the transmission should be:
   a. On the engine.
   b. In the car.
   c. On the bench.
   d. Varies with different makes and models.
4. Name the order in which the major engine components are GENERALLY assembled.
5. The oil placed on parts when assembled will provide adequate lubrication when the engine is first started. True or False?
6. If your answer to question 5 was false, how do you guarantee ample lubrication for the initial starting of the engine?
7. When hooking up a booster battery, connect:
   a. Pos. to Pos. and Neg. to Neg.
   b. Pos. to Neg. and Neg. to Pos.
   c. Pos. and Neg. both to car battery Pos.
   d. Pos. and Neg. both to car battery Neg.
8. Clean, soft water is all that is needed when filling the cooling system. True or False?
9. Place a hose in the radiator and allow it to run while the engine is first started and warmed up. True or False?
10. There are seven very important things that should be double checked before starting the engine. Name them.
11. In order to start after an overhaul, the engine must be primed by pouring gas down the carburetor air horn. True or False?

12. When the engine is first started, it should be operated at ________ rpm until normal operating temperature is reached.
13. Name five things that should be checked during the initial warm-up period.
14. Following the initial warm-up, the ___________ and ___________ should be retorqued.
15. After the warm-up, in addition to retorquing, name three other adjustment checks that should be made.
16. Describe the break-in run procedure.
17. Break-in can also be performed with the engine mounted on a ___________.
18. List three important recommendations or cautions that should be discussed with the owner when the car is delivered.



Phantom view of a rear-engine, rear-wheel drive car. Note the use of four-wheel disc brakes, and a side-mounted radiator with electric fan.



Chapter 19

COOLING SYSTEM SERVICE

After studying this chapter, you will be able to:

- ☐ Explain the role of antifreeze in an engine cooling system.
- ☐ Properly clean a cooling system.
- ☐ Detect leaks in a cooling system.
- ☐ Test a radiator pressure cap.
- ☐ List the safety rules dealing with cooling systems.
- ☐ Inspect and replace cooling system hoses.
- ☐ Inspect, replace, and adjust drive belts.
- ☐ Test and replace a thermostat.
- ☐ Inspect, repair, and replace a water pump.

The automobile engine generates a great deal of heat. About one-third of the heat energy developed by the fuel burning in the cylinders is converted into power to drive the automobile. About a third is wasted and goes out the exhaust unused. The remaining third is absorbed by the metal of the engine and must be disposed of by the cooling system to prevent overheating.

Fig. 19-1 shows the approximate temperatures of the various engine parts while the car is in operation.

Automobile cooling systems, when properly set up and maintained, are quite efficient. There are, however,

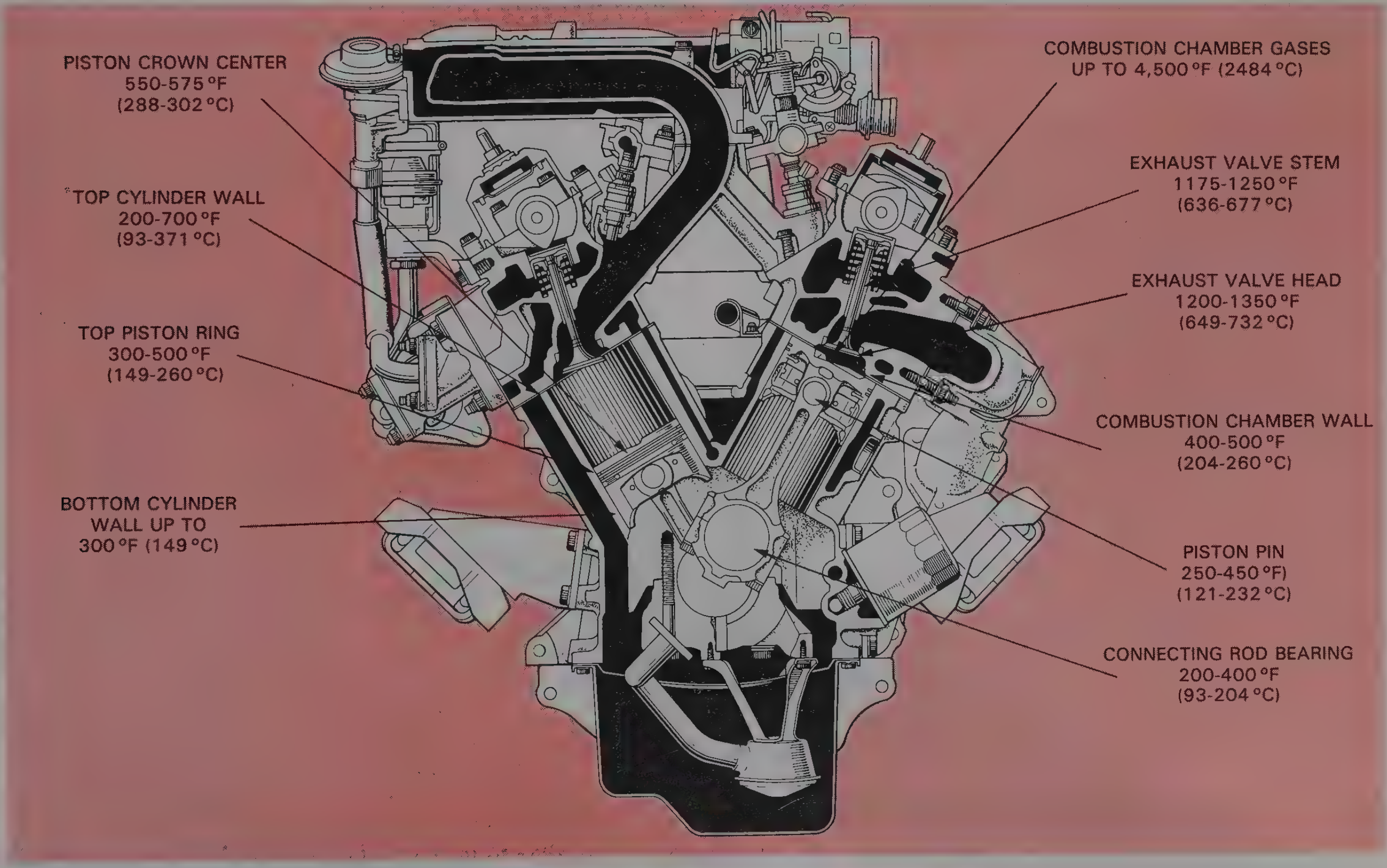

PISTON CROWN CENTER
550-575 °F
(288-302 °C)
TOP CYLINDER WALL
200-700 °F
(93-371 °C)
TOP PISTON RING
300-500 °F
(149-260 °C)
BOTTOM CYLINDER
WALL UP TO
300 °F (149 °C)
COMBUSTION CHAMBER GASES
UP TO 4,500 °F (2484 °C)
EXHAUST VALVE STEM
1175-1250 °F
(636-677 °C)
EXHAUST VALVE HEAD
1200-1350 °F
(649-732 °C)
COMBUSTION CHAMBER WALL
400-500 °F
(204-260 °C)
PISTON PIN
250-450 °F)
(121-232 °C)
CONNECTING ROD BEARING
200-400 °F
(93-204 °C)

Fig. 19-1. Approximate temperatures of various engine components and areas. Temperatures vary depending upon engine design and application. (Dodge)

a number of important units in the system in which a failure or malfunction can lead to serious overheating. Under certain conditions, problems can also cause overcooling.

Regular routine service checkups will usually disclose cooling system problems before they reach the serious stage. It is important for the mechanic to become familiar with problems associated with the cooling system; which units are responsible, how they may be checked and if faulty, how they may be repaired. See Fig. 19-2.

USE SOFT WATER

When filling the cooling system, clean, soft water (water free of heavy lime and other mineral concentrations) should be used. This will help to prevent scale deposits. Scale deposits (hard layers of chemicals built up in certain areas of system, especially in extra hot sections) will drastically reduce the transfer of heat from the metal to the coolant. Water high in mineral content can also cause antifreeze and inhibitors to lower their efficiency and useful life.

ANTIFREEZE

In all areas where the prevailing temperatures may drop below freezing (32°F or 0°C), it is necessary to add an antifreeze solution to the cooling system. The correct amount to use is determined by the capacity of the cooling system, the type of antifreeze, and the lowest anticipated temperature. The manufacturer's instructions should be followed.

NEVER TRY TO ECONOMIZE BY ADDING JUST ENOUGH ANTIFREEZE TO GET BY.

Add sufficient antifreeze to provide full protection. As the winter wears on, the owner may add a certain amount of water to the system. This will dilute and weaken the solution. If a rust inhibitor and water pump lubricant are part of the antifreeze, there must be enough of these agents in the system to provide proper protection from rusting and corrosion.

THREE BASIC ANTIFREEZE SOLUTIONS

Denatured (ethyl) alcohol, methanol (methyl or wood alcohol), and ethylene glycol make up three basic antifreeze solutions.

Ethylene glycol (so called permanent type antifreeze) has several advantages over denatured alcohol or methanol. Ethylene glycol will not cause a fire hazard. It does not harm car finishes, although it can cause minor heat spotting. It does not readily evaporate at normal system temperatures and can be used with a 180°F (82°C) and above thermostat. It can be left in the cooling system, as is done on late model cars, throughout the year.

Ethylene glycol antifreeze is POISONOUS and must

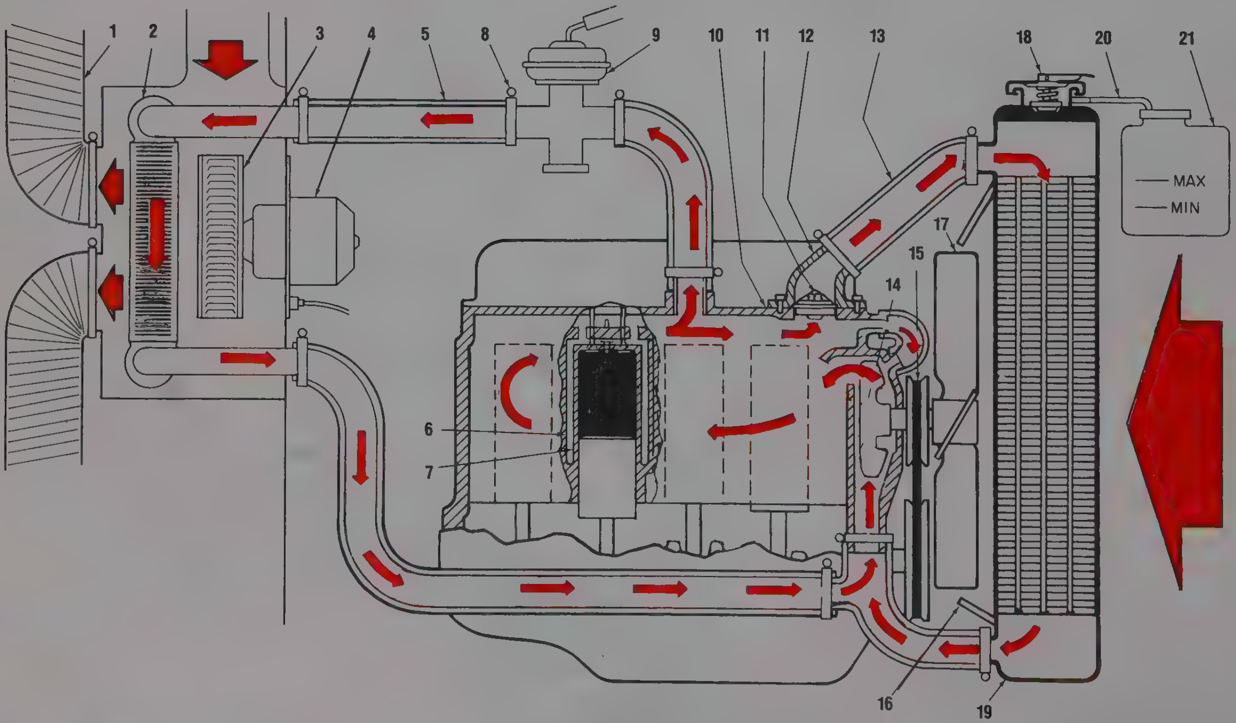


Fig. 19-2. Potential cooling and/or heating system problem areas. 1—Defroster hose. 2—Heater core. 3—Blower wheel and motor. 4—Heater/air conditioning blower motor. 5—Heater hose. 6—Water jacket. 7—Combustion chamber. 8—Hose clamps. 9—Heater control valve. 10—Thermostat gasket. 11—Thermostat. 12—Water outlet. 13—Radiator hose. 14—Water pump. 15—Fan belt. 16—Fan shroud. 17—Fan. 18—Radiator pressure cap. 19—Radiator. 20—Overflow tube. 21—Overflow reservoir tank. (Stant)

NOT be taken internally. Keep away from children. Never put drinks or food in empty antifreeze containers.

Alcohol base antifreeze is flammable, injurious to the car finish, evaporates readily, and should be used only in systems equipped with a 160°F (71°C) or lower thermostat.

Ethylene glycol is widely used in cars today to protect against freezing and to inhibit rust. The antifreeze used must not corrode any of the copper, iron, aluminum, brass, or solder used in parts of the engine in contact with the coolant. Common coolant ratios are around 50 percent water and 50 percent ethylene glycol.

USEFUL LIFE OF ANTIFREEZE

The cooling systems of many new cars are filled at the factory with a solution made up of ethylene glycol antifreeze, rust inhibitors, pump lubricant, and chemically clean water. Unless the solution leaks out to the point that dilution is a problem, it can ordinarily be left in the system for the recommended period of 24 months.

Following the first 24 month period, many car makers insist on the use of permanent type antifreeze year round and failure to comply may result in voiding the new car warranty.

When seasonal changes are desired and permissible, the antifreeze is drained when the cold season is over. The system is flushed; filled with fresh water, and water pump lubricant and rust inhibitor added. When winter again approaches, the system is drained, flushed, and protected with antifreeze in the proper amount.

It is suggested that the recommendations of the car maker be followed regarding type of antifreeze and length of use.

FILLING SYSTEM WITH ANTIFREEZE SOLUTION

Operate the engine until normal temperature is attained (heater control set to maximum heat). Shut off engine. Open the pressure cap carefully. Open radiator drain cock and remove the drain plugs from the engine block.

If the coolant is rusty or if the radiator appears to be scummy inside, the system should be cleaned using a chemical cleaner (procedure is discussed later in this chapter). If not, flush out with clean water.

Following cleaning, when needed, torque head bolts, tighten radiator and heater hose clamps, and make a careful search for signs (rust streaks, discoloration from antifreeze, dampness) of coolant leakage. Repair all leaks. Pressure test system (this procedure is described later in this chapter).

Close drain cock and install block drains. Add about one gallon of CLEAN, SOFT water to the system. Shake the container of antifreeze to mix well and add the required amount to the radiator. Add water until level is at proper height, usually about two inches (50.8 mm) from the bottom of the radiator filler neck (full for closed systems).

Start the engine and run until normal operating temperature is reached. The heater control should be set to maximum heat. When the engine is warm, the thermostat will open and release any air trapped in the system. Running the engine until it becomes warm also mixes the antifreeze and water. For OPEN systems, check radiator level, Fig. 19-3, A and B. It should be within about two inches (50.8 mm) of the bottom of the filler neck. For CLOSED systems, radiator is full and coolant in the reservoir should be at correct level for a warm engine. See Fig. 19-3, C and D. DO NOT REMOVE PRESSURE CAP FROM CLOSED SYSTEM TO CHECK LEVEL! If level in reservoir has RAISED to warm engine level, it is properly filled.

CHECKING ANTIFREEZE

Use a special hydrometer or a refractometer to test coolant protection level at operating temperature. Draw coolant in and out of the hydrometer several times to bring hydrometer temperature up to coolant temperature. When using test unit, follow manufacturer's instructions. See Fig. 19-4.

ROUTINE SYSTEM CLEANING

A mild rust and scale condition in the cooling system can usually be corrected by cleaning with one of a number of available chemical preparations. WHERE AN ALUMINUM RADIATOR IS USED, USE A CLEANER THAT IS HARMLESS TO ALUMINUM.

Some cleaners are of a one-step type while others require two or more separate operations.

In general, the engine is operated until it reaches normal operating temperature. The heater control should be set to maximum heat, allowing coolant and cleaner to circulate through the heater lines and core. Stop the engine. Remove the radiator cap and open the radiator drain cock. Open block drains.

Close all drains. Fill system with clean water and run engine until normal operating temperature is attained. Add cleaner and run the engine the specified length of time. Do not let engine boil. If the car is outside and the weather is very cold, be careful of slush ice forming in the radiator.

Drain the system again. Close all drains and refill with clean water.

NEUTRALIZE AND FLUSH THOROUGHLY

If an acid type cleaner was used, it must be neutralized. Failure to neutralize and flush properly may leave

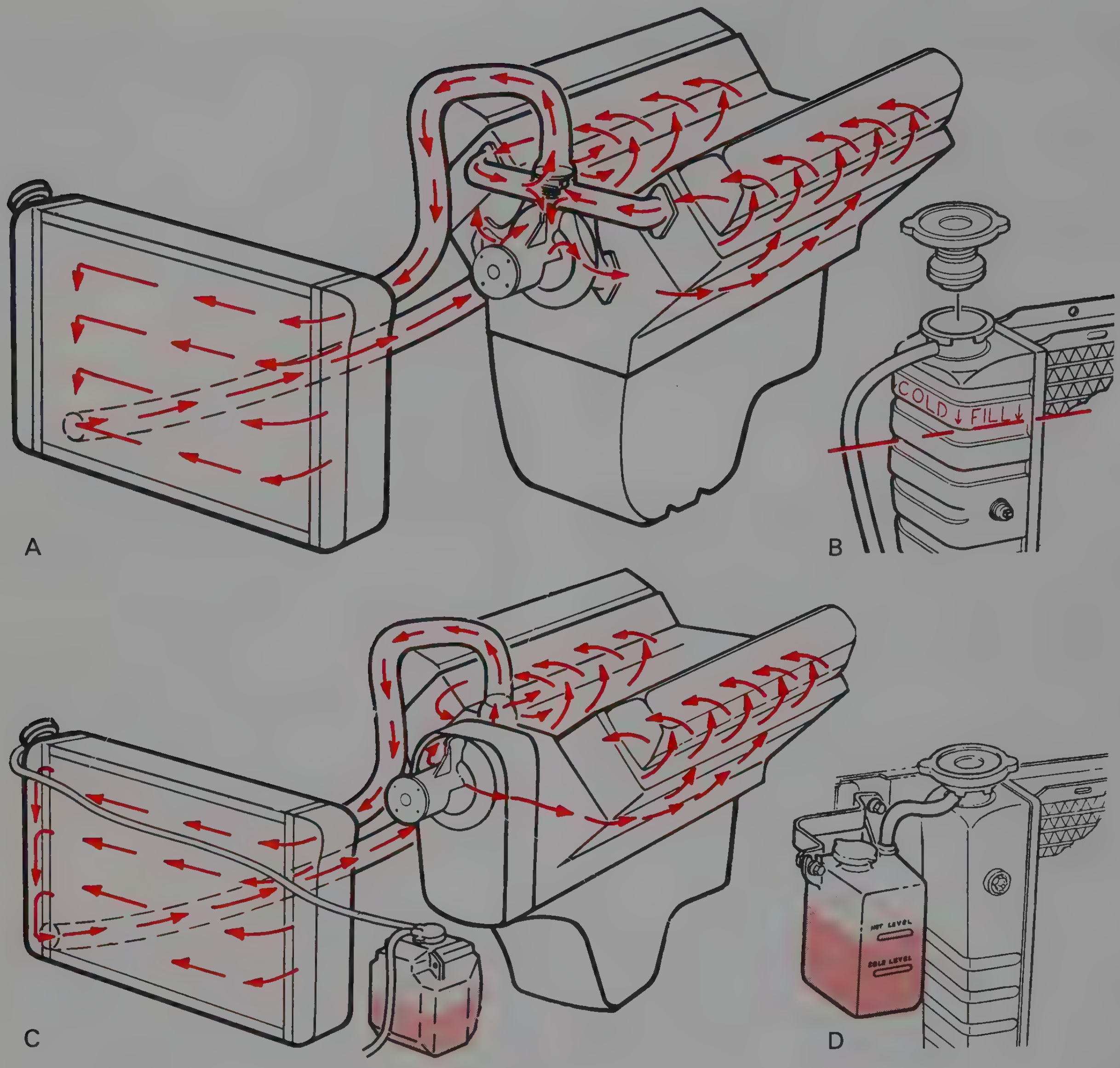


Fig. 19-3. Typical cooling systems. A—Coolant flow in an OPEN system. B—Cold fill level for an OPEN system. Note marks on side tank. C—Coolant flow in a CLOSED system. D—Hot and cold fill level marks on a CLOSED system coolant reservoir. With CLOSED system, coolant level in reservoir falls with engine cooling and rises with engine heating. Radiator always is completely full. (Cadillac and Ford)

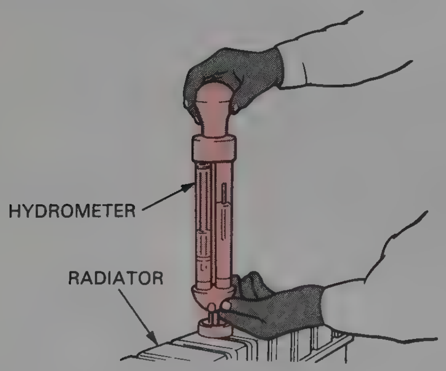


Fig. 19-4. One type of antifreeze hydrometer being used to check concentration (percentage) of antifreeze in system. (Chrysler)

acid which will attack the system and destroy the protective properties of inhibitors and antifreeze.

Pour the neutralizer into the system and heat the system to normal operating temperature. Run for the specified length of time and drain.

Using a coolant mixture of around 50% ethylene glycol antifreeze and 50% clean, soft water, fill the system. Run until normal temperature is reached. Add coolant if needed.

IMPORTANT POINTS IN CLEANING

Heater control should be set on maximum heat during the entire cleaning process. Remove radiator cap while draining. Avoid splashing cleaner on the car finish. Carefully follow the instructions supplied by the manufacturer of the cleaning product.

HEAVY DUTY SYSTEM CLEANING

Long periods of neglect often result in a cooling system that is literally choked with rust and scale. Ultimately the tubes are blocked enough to cause the system to boil. The boiling action breaks loose large quantities of scale that may plug the radiator completely. See Fig. 19-5.

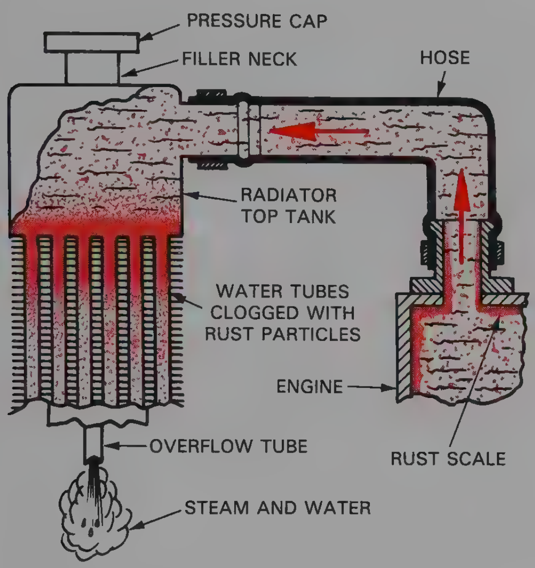

PRESSURE CAP
FILLER NECK
HOSE
RADIATOR TOP TANK
WATER TUBES CLOGGED WITH RUST PARTICLES
ENGINE
OVERFLOW TUBE
RUST SCALE
STEAM AND WATER

Fig. 19-5. Note how rust particles have completely clogged water tubes in this radiator.

RADIATOR REVERSE FLUSHING

A system in bad condition, as shown in Fig. 19-5, may be cleaned by REVERSE FLUSHING, using power equipment. Reverse flushing forces water through the system in a direction opposite to that of normal flow. This facilitates the removal of particles jammed into openings. Severe radiator clogging may require removal and boiling in a hot tank. (The procedure is described later in this chapter.)

To reverse flush the system, torque the head bolts. A cleaning agent is then used following manufacturer's instructions.

Remove both upper and lower radiator hoses. Disconnect heater hoses. Attach the flushing gun to the lower radiator outlet and a lead away hose to the top radiator outlet. Replace the radiator cap. See Fig. 19-6.

Run a stream of water through the radiator and admit periodic blasts of air to agitate and loosen particles so they may be flushed out. Do not exceed a maximum air pressure of 20 psi (138 kPa). Pressure higher than this may rupture the radiator.

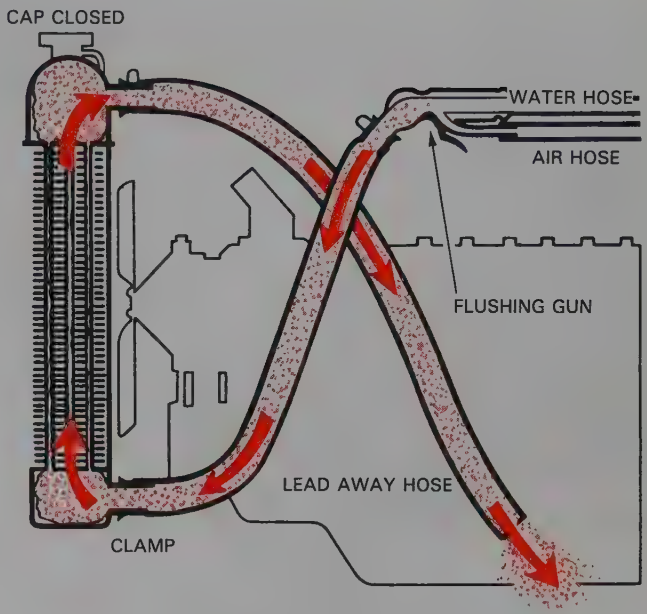

CAP CLOSED
WATER HOSE
AIR HOSE
FLUSHING GUN
LEAD AWAY HOSE
CLAMP

Fig. 19-6. Setup for reverse flushing radiator. (Harrison Radiator)

Continue the flushing and air blasting until the water which flows through the radiator is clear.

REVERSE FLUSHING ENGINE BLOCK

Be sure to remove ALL thermostats from the engine block. Some cars require the removal of the water pump as pressure flushing can damage the seal.

Attach the flushing gun to the block TOP water outlet. Attach a lead away hose to the BOTTOM outlet (if needed). Reverse flush using the same general procedure described for the radiator. See Fig. 19-7.

SOME HEATER SYSTEMS CANNOT BE REVERSE FLUSHED

The flushing gun may be used to flush the heater system. Some cannot be reverse flushed. Check

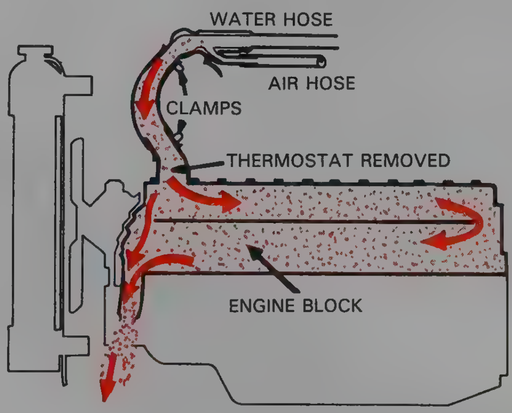

WATER HOSE
AIR HOSE
CLAMPS
THERMOSTAT REMOVED
ENGINE BLOCK

Fig. 19-7. Reverse flushing engine.

manufacturer's recommendations.

After flushing, attach all hoses securely. Fill system with water, add antifreeze or inhibitor as needed. Test system for leaks.

FINDING SMALL EXTERNAL LEAKS IN COOLING SYSTEM

System cleaning may open tiny cracks or other openings that have been sealed with rust. Removal of the rust allows leakage to start again. To check for the possibility of leakage following cleaning (or any time system slowly loses water and no leaks are visible), the system should be pressure tested or checked with a black light and dye, Fig. 19-8.

PRESSURE TESTING COOLING SYSTEM

Fill radiator to within 1/2 in. (12.7 mm) of the filler neck. Attach a pressurizing pump to the filler neck.

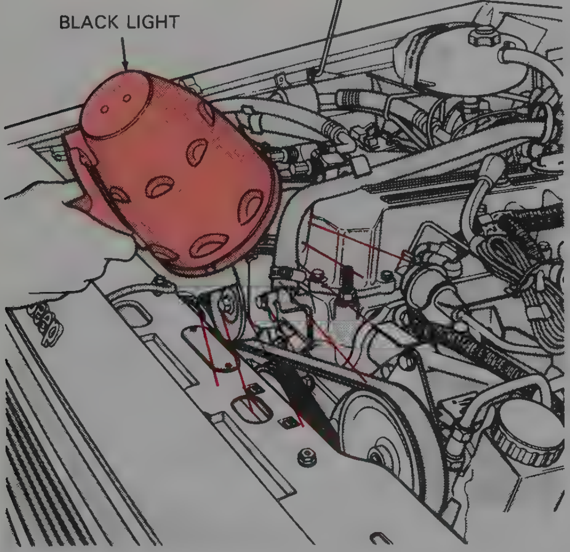


Fig. 19-8. Using black light to detect coolant leaks. Add proper dye, warm engine (use pressure tester on cold engine), and direct light at suspected leak area. Dye will glow when illuminated by the black light. (Jeep)

Build up pressure in the system carefully. Do not exceed the pressure for which the system is designed. Check the pressure marking on the radiator cap or obtain information from the manufacturer's manual. See Fig. 19-9.

When the system is pressurized, watch the gauge. If the pressure holds steady, the system is probably all right. If the pressure drops, check all areas for leaks. If none can be seen, check the pressure pump filler neck connection to make certain it is not leaking.

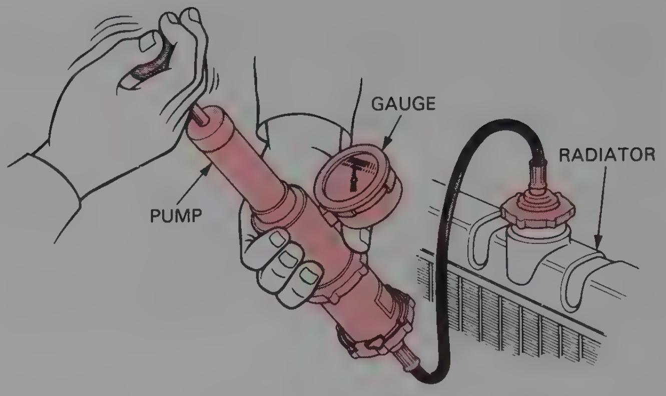


Fig. 19-9. Pressurizing pump attached to radiator. Pressure is being built up in system to check for possible leaks. (Toyota)

Remove the pressure pump. Replace the radiator cap and run the engine until normal temperature is reached. Remove the cap. Attach the pressure pump and once again pressurize the system. Recheck for leaks.

Occasionally you will find that a system leaks only when cold or when hot. By checking before running and after engine warm-up, both types of leaks will be exposed.

Look CAREFULLY for leaks. Even dampness indicates enough loss of coolant to cause trouble.

When finished with the pressure test, adjust coolant to proper level in the radiator.

CHECKING FOR INTERNAL LEAKS— PRESSURE GAUGE

If the system loses coolant and no external source is found, check for internal leakage.

Apply 6 to 8 psi (41-55 kPa) of pressure to the system. Run the engine at slow speed and watch the pressure pump gauge. Pressure buildup indicates a combustion leak—cracked head, blown gasket, or other problem. DO NOT ALLOW PRESSURE TO BUILD UP BEYOND PRESSURE CAP RATING.

To determine which bank (V-type engine) is leaking, disconnect all spark plug wires on one bank. Run engine. If the pressure buildup stops, the leak is in that bank. If not, leak is in the firing bank. Test both banks carefully.

CHECKING FOR INTERNAL LEAKS— TEST CHEMICALS

By drawing the air from the top of the radiator through a special test chemical, it is possible to detect COMBUSTION leaks. The special fluid will change color if combustion gases are present in the system.

On V-type engines, operate on one bank and test. Then operate on the other bank and test. In this way, you can determine if one or both banks contain a leak. Fig. 19-10 illustrates a leak detector tool.

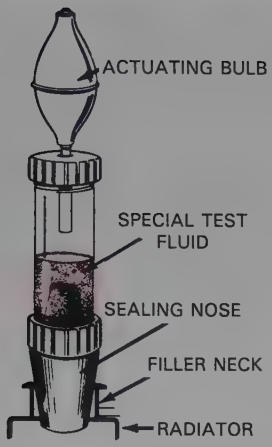


Fig. 19-10. Combustion leak detector. Note special fluid. (P and G Mfg. Co.)

OTHER CHECKS FOR INTERNAL LEAKS

Drain the system down to the level of the engine outlet hose. Remove hose. Add coolant if needed to bring level up to hose fitting neck. Disconnect water pump drive belt. Start engine and accelerate rapidly several times. Watch for bubbles or for a surge in the water level, either one of which indicates a combustion leak.

Pull the engine oil dipstick. Tiny water droplets in the oil clinging to the stick indicate internal leakage.

Oil in the radiator may indicate a combustion leak or a leak in the transmission oil cooler.

When draining the oil, always watch for water pollution.

Water or steam discharge from the tail pipe, with the engine operating at normal temperature, can mean internal leakage. Water discharge is normal during warmup.

If coolant containing ethylene glycol leaks into the cylinders, it may plug the rings and cause hard starting, excessive oil consumption, piston corrosion, and bearing failure.

If internal leaks are discovered, the oil should be drained. If ethylene glycol was being used as an antifreeze, the lubrication system should be thoroughly flushed. A special flushing agent is required to dissolve the gummy residue deposited by the antifreeze. In cases of severe contamination, proper cleaning may require an engine teardown.

PRESSURE CAPS FOR RADIATORS

The radiator cap must fit properly so pressure may be maintained in the cooling system. With a pressurized system, a car engine can run hotter (at more desirable operating temperature) without boiling the coolant, than is possible without radiator pressure.

The boiling point of water under pressure is raised about 3°F (1.6°C) for each pound of pressure added. If pressure buildup permitted by the radiator cap is 15 psi, the boiling point of the coolant under pressure will be increased by 15 x 3 or 45°F. At sea level, water boils at 212°F (100°C). Adding 45°F to 212°F gives us 257°F, the temperature at which radiator coolant will boil when placed under 15 psi of pressure. To maintain specified pressure, the cap pressure valve spring and seal surface must be in good condition, Fig. 19-11.

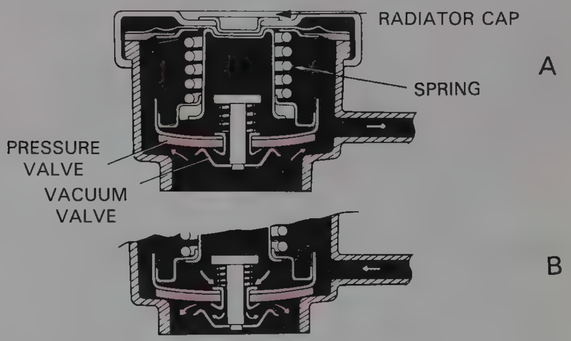


Fig. 19-11. Parts of the radiator cap. A—Pressure valve is forced off its seat when specified psi is reached. B—Vacuum valve is lowered, allowing atmosphere pressure into radiator and preventing its collapse. (Suzuki)

You can check the operation of the cap by using a pressure tester, Fig. 19-12.

The cap should retain a pressure within 1-1/2 psi (10 kPa, plus or minus) of the rating specified by the manufacturer. If the cap fails to pass the test, discard and replace it with a new cap of the CORRECT PRESSURE RATING. USE AN ALUMINUM CAP ON AN ALUMINUM RADIATOR. DO NOT USE A

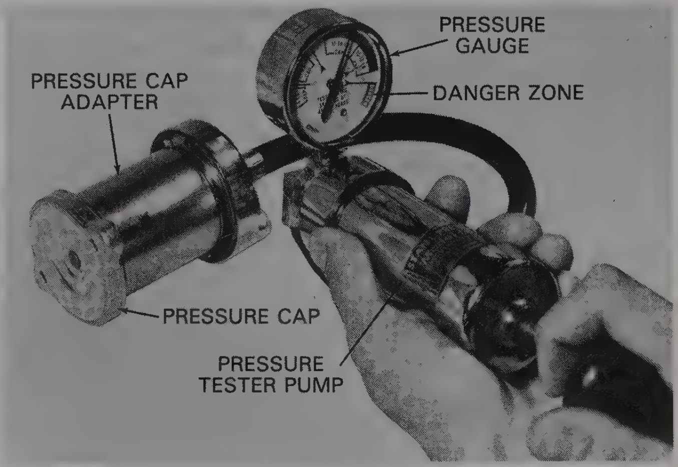


Fig. 19-12. Using a pressure tester to check radiator pressure cap function. This particular tester can be used for checking both the radiator and pressure cap. Note "danger zone" on gauge. NEVER raise pressure to this level! (Stant)

NONPRESSURE CAP ON A PRESSURIZED SYSTEM. DO NOT USE AN OPEN SYSTEM (no coolant reservoir) CAP ON A CLOSED (coolant recovery reservoir) SYSTEM.

DANGER—BURNS

REMOVING A PRESSURE CAP FROM A HOT RADIATOR CAN BE VERY DANGEROUS. SUDDEN RELEASE OF THE PRESSURE MAY CAUSE THE WATER TO FORM INTO STEAM AND LITERALLY "EXPLODE" INTO THE FACE OF THE PERSON REMOVING THE PRESSURE CAP. ALWAYS PLACE A PROTECTIVE RAG OVER THE CAP. STAND TO ONE SIDE. OPEN CAP TO THE SAFETY STOP AND WAIT FOR STEAM PRESSURE TO SUBSIDE. CAP MAY THEN BE SAFELY REMOVED.

WORKING WITH OVERHEATED ENGINE

If the engine is GREATLY overheated (steam is spurting from overflow) SHUT IT DOWN AT ONCE.

If an engine is moderately overheated, it is best to idle the engine for a minute or so before shutting it down. Flow of the coolant helps to carry excess heat from the cylinders and valves, and there is less possibility of cylinder distortion and warped valves.

Never run cold water into the radiator of an overheated engine. Raise the hood and allow the engine to cool down until it is no longer boiling. Then, start the engine. While running at a fast idle, slowly add water to the radiator (pump mixes hot and cold water). Run engine until temperature is normal, then recheck radiator coolant level.

INSPECT RADIATOR FILLER NECK

Check the condition of the inside sealing seat in the filler neck. It must be smooth and clean. Moderate roughness can be removed with a special reaming tool.

Cam edges must be true and the overflow tube clean and free of dents. A pressure cap cannot function properly unless the filler neck is in good condition. See Fig. 19-13.

HOSE INSPECTION

Visually check all hoses for signs of deterioration. Squeeze the hose. A hose should not be hard and brittle, nor should it be soft and swollen. See Fig. 19-14 and 19-15.

Bend heater hoses to check for surface cracking, abnormal swelling, and hardness. If any show signs of deterioration, they should be replaced.

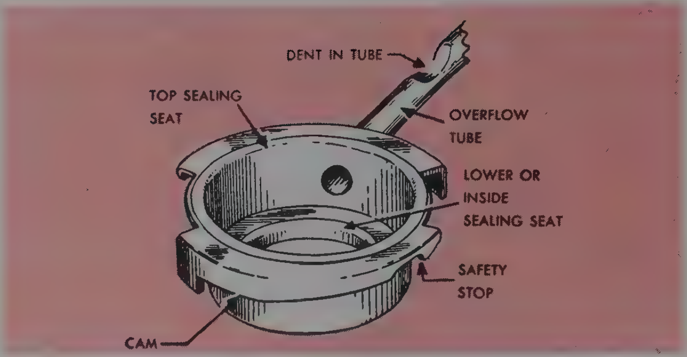


Fig. 19-13. Inspect radiator filler neck for signs of damage. Note dent in overflow tube. (Stant Mfg. Co.)

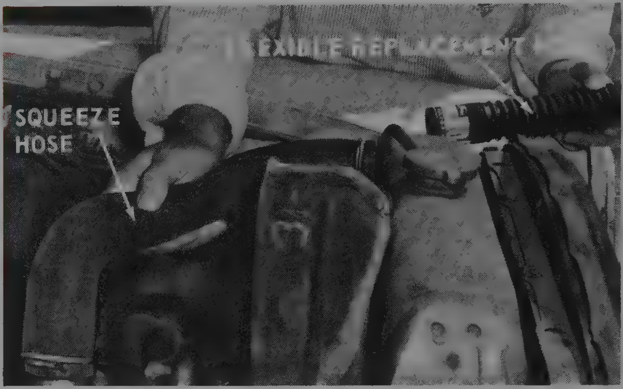


Fig. 19-14. Squeeze radiator hoses to check for hardness or for swelling and softness. (Gates Rubber Co.)

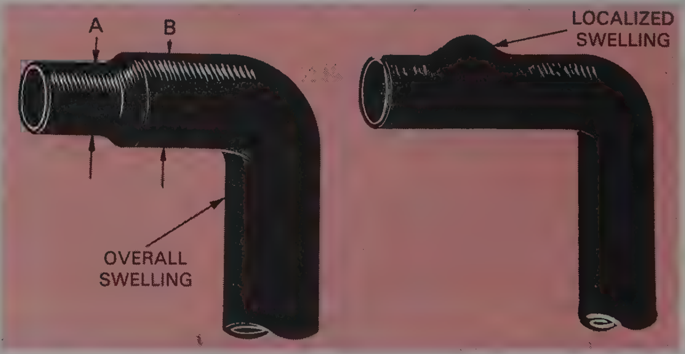


Fig. 19-15. Overall and localized swelling of a radiator hose. Note dimensions. A—Normal diameter. B—Swollen diameter. A hose with any abnormal swelling should be replaced. (Toyota)

The radiator hose in Fig. 19-16 has deteriorated badly. The outside is cracked. The cloth reinforcement has rotted. The inside is split and filled with loose particles of hose and rust scale.

Pay careful attention to the bottom radiator hose. It is under a vacuum and, if soft, will collapse and cut off the coolant circulation. If the bottom hose is loose or cracked, it can also admit air into the system. Aeration (air bubbles in system) can cause rust to form faster than normal. Aeration can be caused by air sucked into

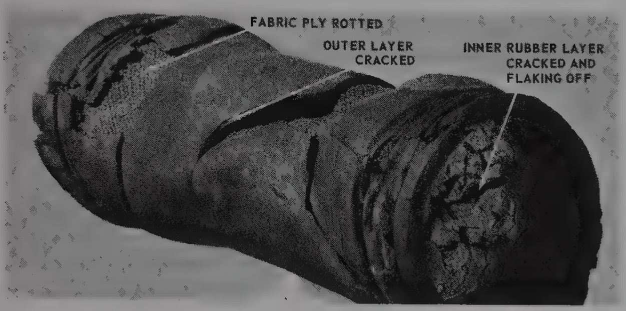

FABRIC PLY ROTTED
OUTER LAYER CRACKED
INNER RUBBER LAYER CRACKED AND FLAKING OFF

Fig. 19-16. This hose should have been replaced long before reaching this advanced state of deterioration.

the system at the lower hose or through the water pump seal, by combustion gases being forced into the coolant, and by heavy surging in the top radiator tank.

When a hose rots on the inside, the rubber particles may break off and be carried into the radiator and cause clogging.

IF THERE IS THE SLIGHTEST DOUBT AS TO THE CONDITION OF A HOSE, REPLACE IT.

HOSE REPLACEMENT

Read the section in Chapter 5 on hose.

Use replacement hose of the correct inside diameter. Do not use a rigid hose between radiator and engine as the normal movement of the engine can cause the radiator hose fittings to crack loose and leak. Relatively soft, molded type hose is satisfactory for this purpose as well as flexible accordion type hose.

If the hose placed on the car by the manufacturer contains a spiral wire inside to prevent collapse, make certain the same type of hose is used for replacement. If the spiral wire is badly rusted, replace it.

When installing a new hose, clean the metal hose fitting and coat the fitting with a thin layer of nonhardening gasket cement. Do not coat the inside of the hose as gasket cement may be scraped off into the system. The proper method for cementing a hose is shown in Fig. 19-17.

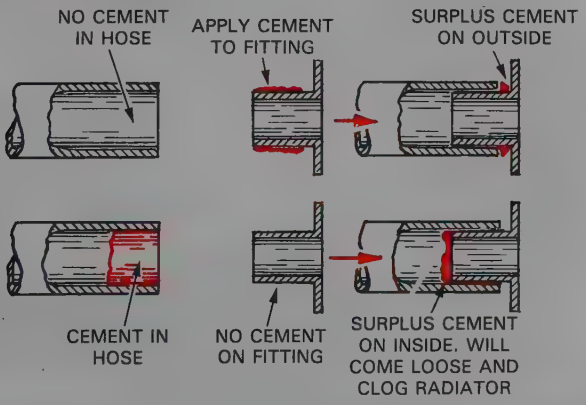

NO CEMENT IN HOSE
APPLY CEMENT TO FITTING
SURPLUS CEMENT ON OUTSIDE
CEMENT IN HOSE
NO CEMENT ON FITTING
SURPLUS CEMENT ON INSIDE. WILL COME LOOSE AND CLOG RADIATOR

Fig. 19-17. Coat the hose fitting—NOT THE HOSE.

Make certain the hose ends pass over the raised sections of the fittings far enough to position clamps properly. Before securing clamps, make certain any factory alignment marks used on hoses and radiator are lined up, Fig. 19-18.

If the hose must bend, use either a special shaped molded hose or the flexible type. Fig. 19-19 illustrates hose replacement steps.

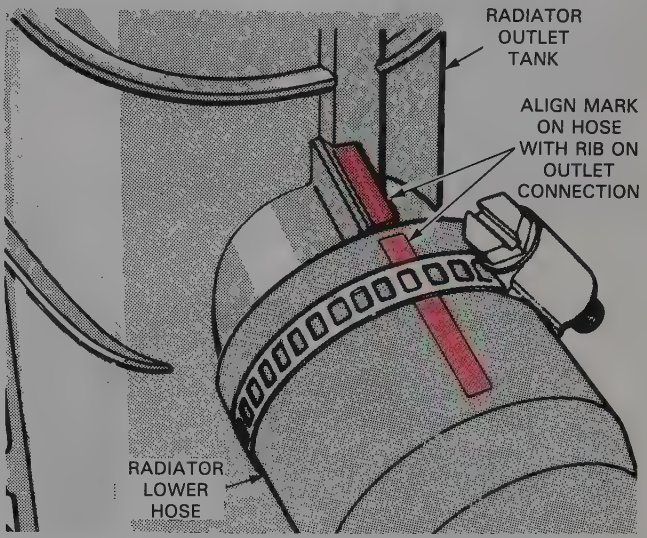

RADIATOR OUTLET TANK
ALIGN MARK ON HOSE WITH RIB ON OUTLET CONNECTION
RADIATOR LOWER HOSE

Fig. 19-18. This illustrates proper alignment of lower radiator hose to outlet tank. A twist in hose (not aligned) would place strain on tank that could cause tank to crack or break prematurely. (Ford)

DRIVE BELT INSPECTION

Grasp each drive belt and roll it around so that the bottom and one side are clearly visible. Look for signs of cracking, oil soaking, hard glazed contact surface, splitting or fraying. Replace belts showing these signs as well as belts older than around four years, Fig. 19-20. Modern belts may look ok, but often fail suddenly from aging. Broken belts can be both inconvenient and DANGEROUS!

BELT REPLACEMENT

Disconnect battery ground clamp before removing belt. Slack off alternator, power steering pump, any other units, and remove belt. Make sure the replacement belt is of the correct width, length, and construction.

Clean oil and grease from pulley surfaces and install the new belt. If the belt has a directional arrow, install so the arrow faces in the direction of belt travel. Adjust belt tension. When matched belts are being replaced, make sure new belts of exactly the same length are used. Do not force a belt over the pulley edges with a screwdriver or pry bar.

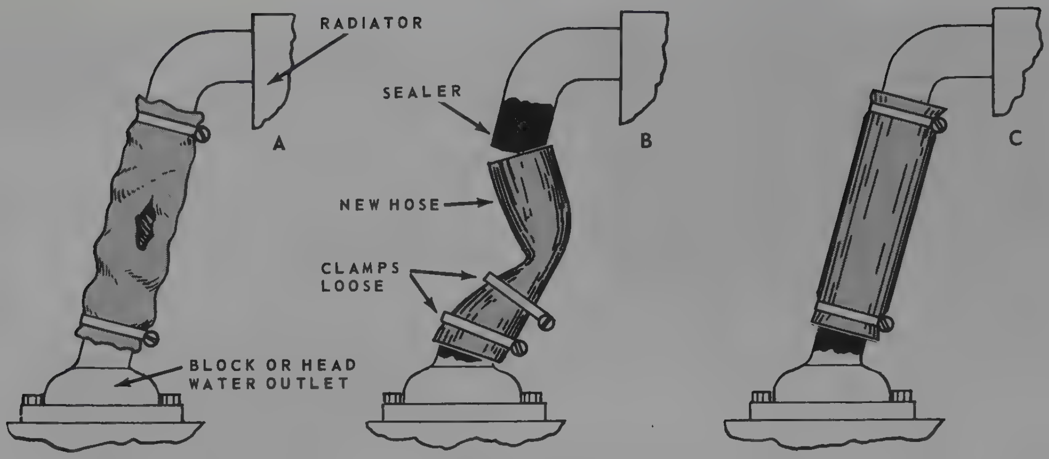


Fig. 19-19. Typical steps in water hose service. A—Inspect and remove old hose if needed. B—Coat fittings with sealer. Place clamps loosely on hose. Crimp hose to install. C—Center hose on fittings and tighten clamps.

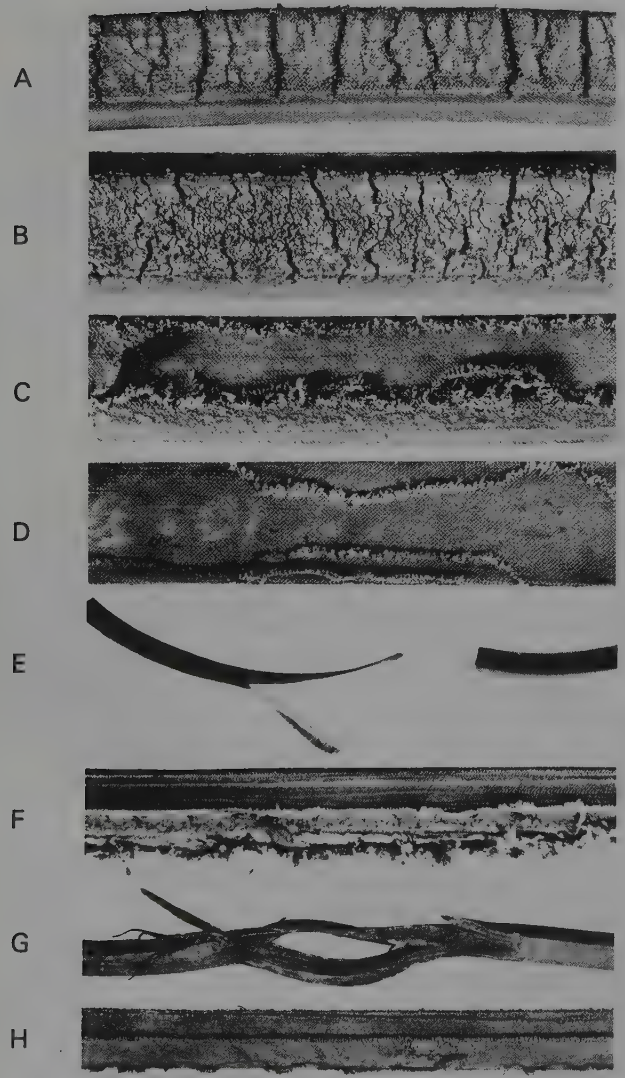


Fig. 19-20. Some drive belt wear signs. Replace such belts. A—Bottom cracked. B—Bottom cracked. C—Broken fabric. D—Top cover fabric torn. E—Burned from slipping. F—Gouged edge. G—Broken cord material. H—Side wear. (Deere & Co.)

ADJUSTING BELT TENSION

There are several methods that may be used to adjust belt tension. One method involves deflecting the belt inward and measuring the amount of deflection under a certain pressure. Fig. 19-21 shows this method and the recommended specifications for pressure and deflection for this particular setup. Keep in mind that the specifications will vary with different engines. Always follow manufacturer's directions.

Another way to check belt tension is to utilize a special belt strand tension gauge. The gauge deflects the belt and indicates belt tension on a dial, Fig. 19-22. This gauge can be used to check both the conventional, cogged V-belts, and ribbed belts. See Fig. 19-23.

Be sure all belts, especially the ribbed type, are properly seated in their pulleys before measuring tension, Fig. 19-24.

Belt tension can also be determined by measuring the torque applied to the generator (alternator), power steering pump, and other unit pulley until it slips on

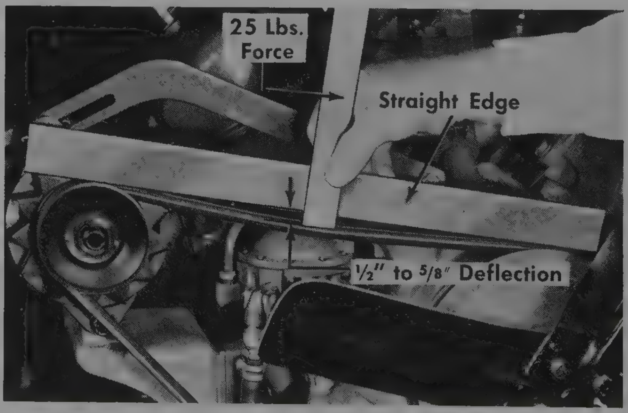


Fig. 19-21. Checking belt tension by measuring amount of belt deflection under a specific amount of pressure. (G.M.C.)

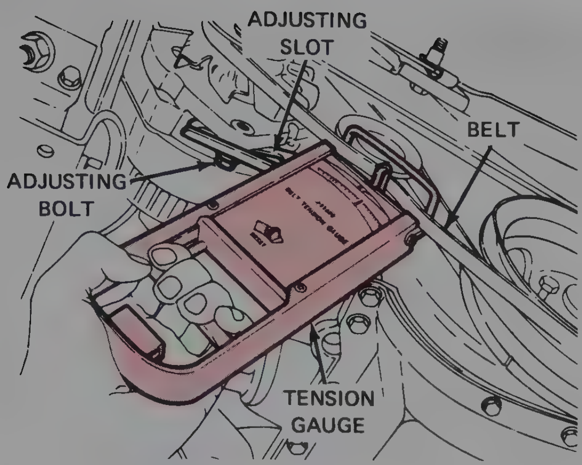

ADJUSTING SLOT
BELT
ADJUSTING BOLT
TENSION GAUGE

Fig. 19-22. Checking belt tension with a belt strand tension gauge. (American Motors)

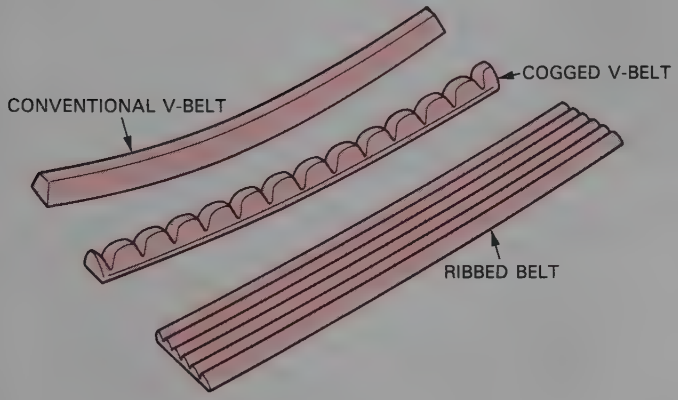

CONVENTIONAL V-BELT
COGGED V-BELT
RIBBED BELT

Fig. 19-23. Three common types of drive belts. Each serves a specific purpose. (Ford)

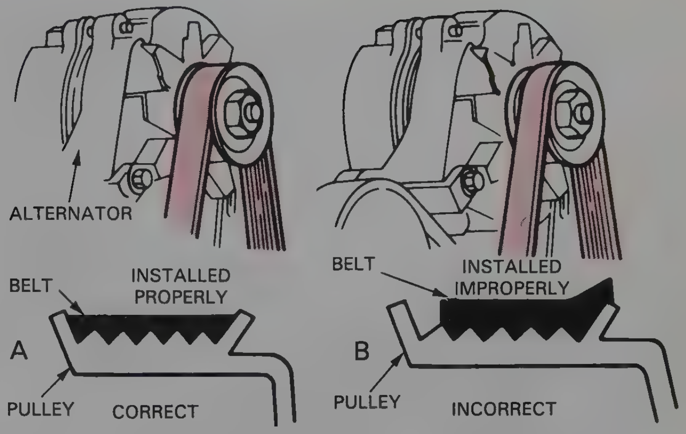

ALTERNATOR
BELT
INSTALLED PROPERLY
A
PULLEY
CORRECT
BELT
INSTALLED IMPROPERLY
B
PULLEY
INCORRECT

Fig. 19-24. A—Ribbed belt is properly seated. B-Belt has been installed on pulley incorrectly. This belt will give a false tension reading. (Ford)

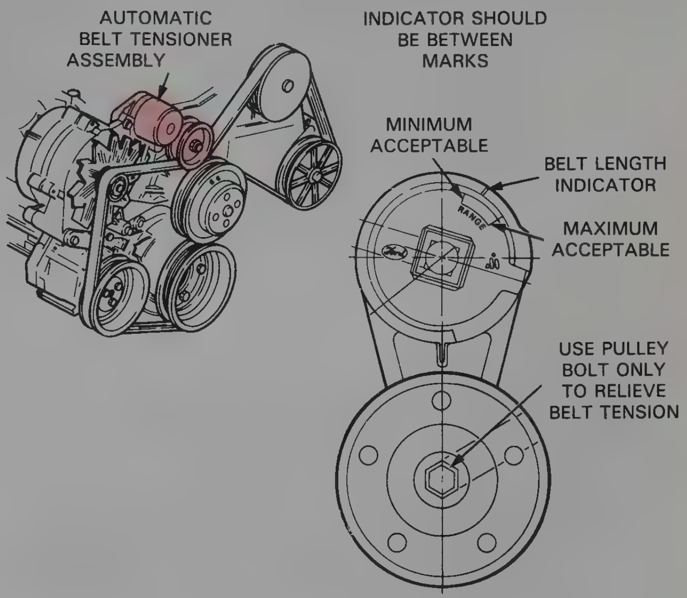

AUTOMATIC BELT TENSIONER ASSEMBLY
INDICATOR SHOULD BE BETWEEN MARKS
MINIMUM ACCEPTABLE
BELT LENGTH INDICATOR
RANGE
MAXIMUM ACCEPTABLE
USE PULLEY BOLT ONLY TO RELIEVE BELT TENSION

Fig. 19-25. Spring-loaded belt tensioner. Note the acceptable belt length indicator. (Ford)

the belt.

An automatic belt tensioner is used to maintain proper tension, Fig. 19-25.

TENSIONING SPECIFICATIONS

Specifications for tensioning a NEW belt will be somewhat different from those for tensioning a USED belt. Any belt that has been tensioned and placed in operation for a period of 10 or 15 minutes should be considered a USED belt for purposes of retensioning.

PROPER BELT TENSIONING IS IMPORTANT

A properly tensioned belt will run quietly and will provide maximum service life. Power steering pump action, alternator output, compressor, and water pump efficiency will be maintained.

A loose belt will squeal, flap, and reduce the efficiency of the pump, generator (alternator), or other unit. Belt life will be greatly reduced.

A belt that is too tight will place the generator (alternator), water pump, or other unit bearings under a heavy strain and will cause premature wear. Constant strain on the belt will also cause belt breakage. Always tension belts carefully. Use manufacturer's specifications.

FAN BLADES

Replace fan when blades are bent or cracked. Do not weld or braze. Never attempt to straighten fan blades which are badly bent. When installing, use a spacer where required and torque fasteners. Never stand in line with a revolving fan. Keep fingers away from blades. Remove battery ground clamp before working on fan.

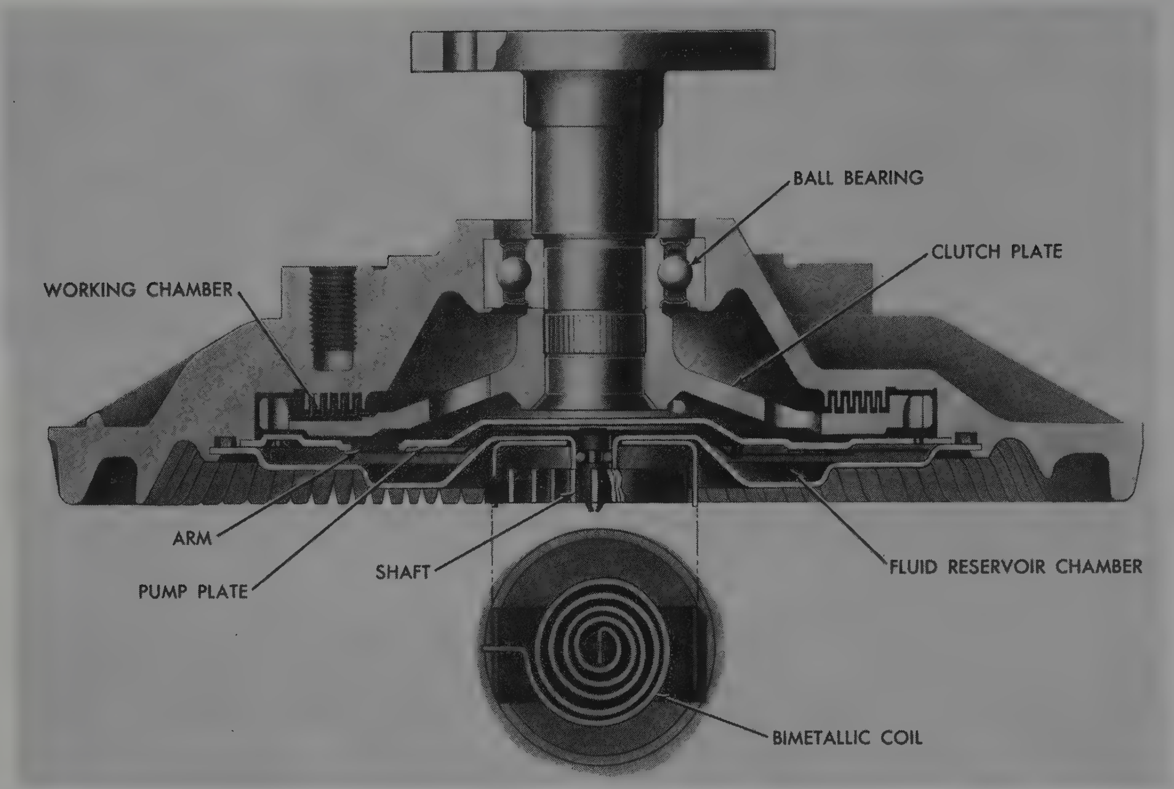


Fig. 19-26. Fluid drive fan unit. Note fins on drive unit used to conduct heat generated by slippage in silicone fluid. (Chevrolet)

FLUID DRIVE FAN

The fluid drive fan uses silicone oil, sealed in a drive clutch assembly, to separate the fan blades from the fan pulley.

As engine speed increases, the torque required to turn the fan also increases. At a predetermined speed (about 2500 to 3200 rpm), the silicone driving fluid in the clutch allows enough slippage to limit maximum fan blade rpm. See Fig. 19-26.

Some models of drive fan use either a bimetallic strip or a bimetallic spring that senses radiator temperature. The bimetallic spring operates a valve that can be designed either to start the fan turning when the temperature indicates the need or to alter the maximum rpm in accordance with cooling needs.

CHECKING FLUID DRIVE FAN OPERATION

The fluid drive fan clutch unit is sealed. When it is defective, it should be replaced. Silicone oil leaking from the unit, a broken or stuck spring, or a faulty valve can render the unit inoperative.

The unit illustrated in Fig. 19-27 can be checked by running the engine until normal operating temperature is reached. Turn off the engine. Using a rag to protect your hand (battery ground strap removed), attempt to rotate the fan. Considerable effort should be required.

If the fan turns readily, disassemble the unit and inspect the bimetallic strip for damage. Remove the control piston and polish with crocus cloth. Wipe all parts clean (do not immerse in cleaning fluid), reassemble, and retest. If still inoperative, replace entire clutch unit. It is possible to replace only the bimetallic strip or control piston if they are defective. The replacement piston must be adjusted to the exact length of the original.

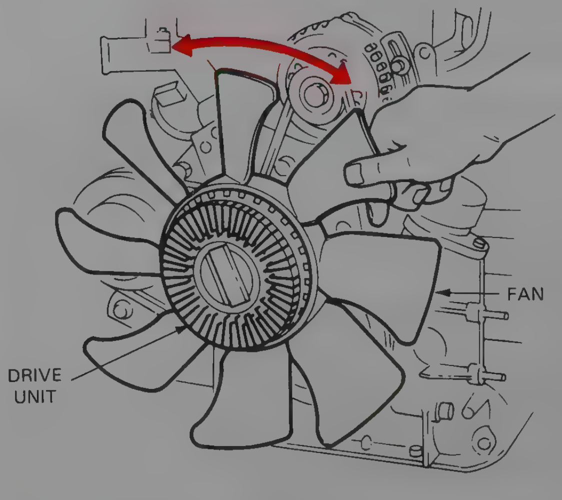


Fig. 19-27. Checking the fan fluid drive unit. ALWAYS remove battery cable. (Mazda)

ELECTRIC FANS

Some vehicles use an electric motor driven fan for cooling, instead of the conventional belt driven unit. One type of electric fan assembly is pictured in Fig. 19-28.

ELECTRIC FAN OPERATION

The fan motor is turned on and off by a temperature sensitive electrical thermostat. The thermostat may be mounted in the radiator tank, heater hose, or block. When the coolant temperature reaches a certain level, electrical contacts in the thermostat close and the fan starts. When the coolant temperature drops sufficiently, the thermostat will open and break the circuit. This causes the fan to stop. On vehicles equipped with air conditioning, the fan is generally on when the air conditioning compressor is activated.

CAUTION! If the ignition switch is in the on or accessory position and the coolant temperature is hot enough, the fan could come on at any time. ALWAYS disconnect the battery before working on or near the fan assembly.

The fans on these units are generally not serviceable. Never attempt to solder, weld, or glue the fan hub or blades together if they are cracked, broken off, or damaged. The motor, when proven to be defective (bent shaft, burned out), should be replaced with a unit specifically designed for the vehicle. Always follow the manufacturer's recommendations. A motor, fan, and fan retainer clip are shown in Fig. 19-29.

TESTING A THERMOSTAT

The thermostat (some engines use several) can cause overheating by either failing to open or by not opening enough. The result can be a cracked block or head,

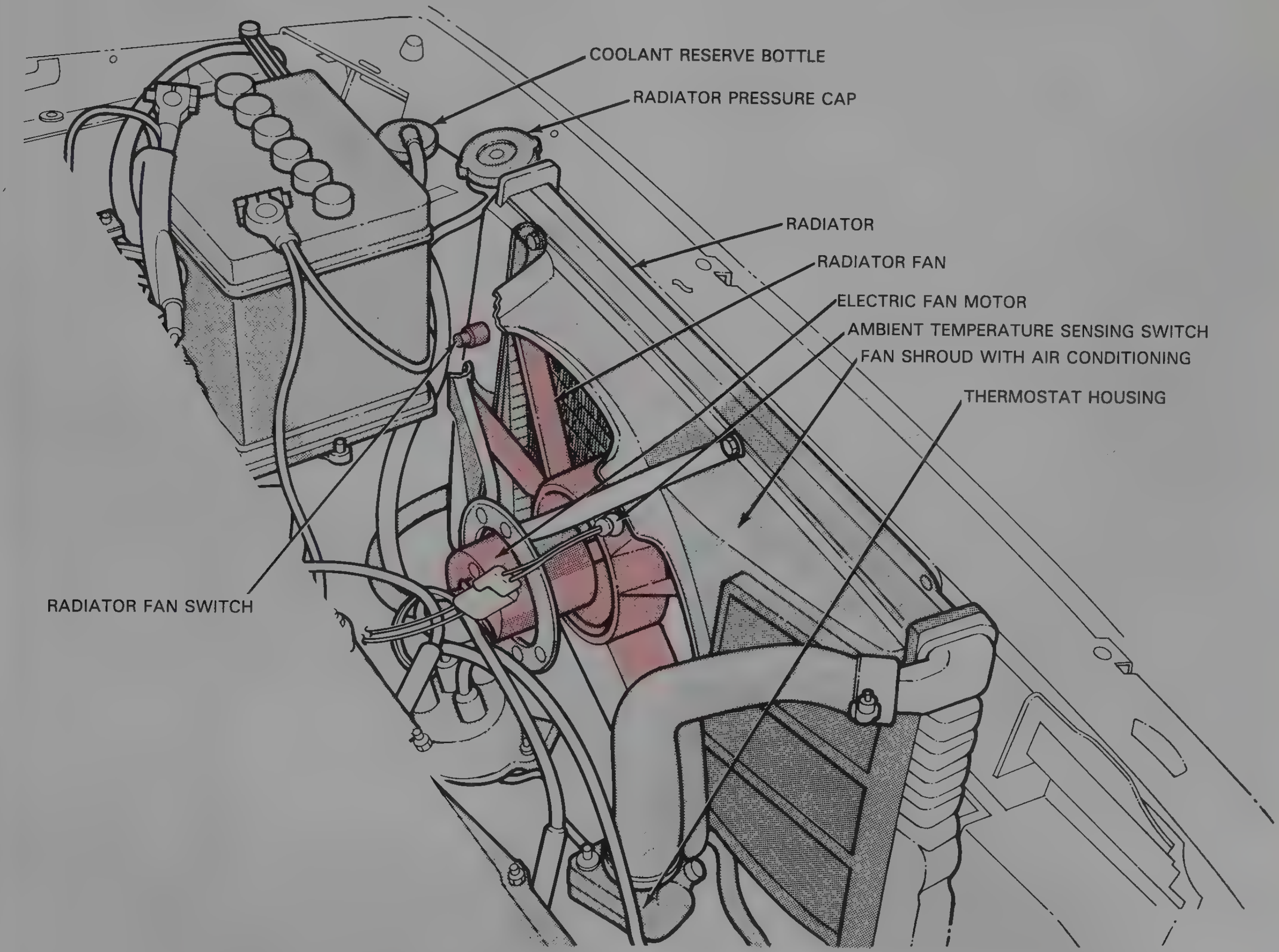

COOLANT RESERVE BOTTLE
RADIATOR PRESSURE CAP
RADIATOR
RADIATOR FAN
ELECTRIC FAN MOTOR
AMBIENT TEMPERATURE SENSING SWITCH
FAN SHROUD WITH AIR CONDITIONING
THERMOSTAT HOUSING
RADIATOR FAN SWITCH

Fig. 19-28. One type of electrically driven fan assembly. This unit uses a five bladed plastic fan. Fan motor only runs when coolant temperature reaches 193-207 °F (89-97 °C) or when air conditioning is on. (Chrysler)

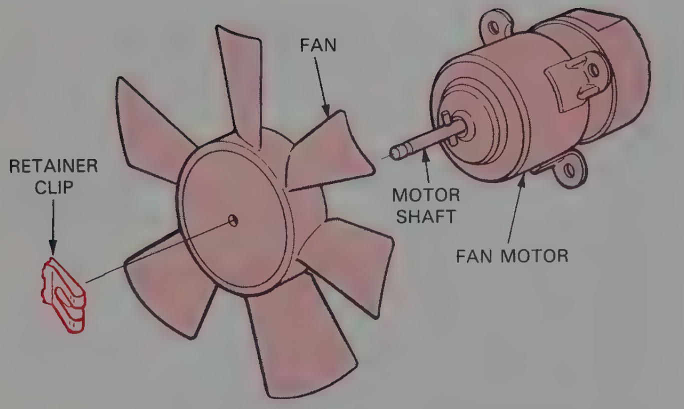


Fig. 19-29. One type of plastic fan and electric fan motor. Note retainer clip which secures fan to motor shaft. (Ford)

extra carbon formation, detonation, burned valves, or bearing damage. Overcooling (engine running too cool) can result from a thermostat sticking in the open position. Damage can include crankcase sludging, poor fuel vaporization, and oil dilution.

When the thermostat is suspected, drain the system (save coolant if clean) until the coolant level is below the thermostat housing. Remove the housing or housing cap. Remove and rinse thermostat. In Fig. 19-30, the housing is off and the thermostat is removed.

Inspect the thermostat valve. It should be closed snugly. Hold it against the light to determine how well the valve contacts the seat. A spot or two of light showing is not cause for rejection. If light shows all around the valve, discard the thermostat.

To check opening temperature, suspend the thermostat, pellet down, in a container of water. The thermostat must be completely submerged and must not touch the container sides or bottom.

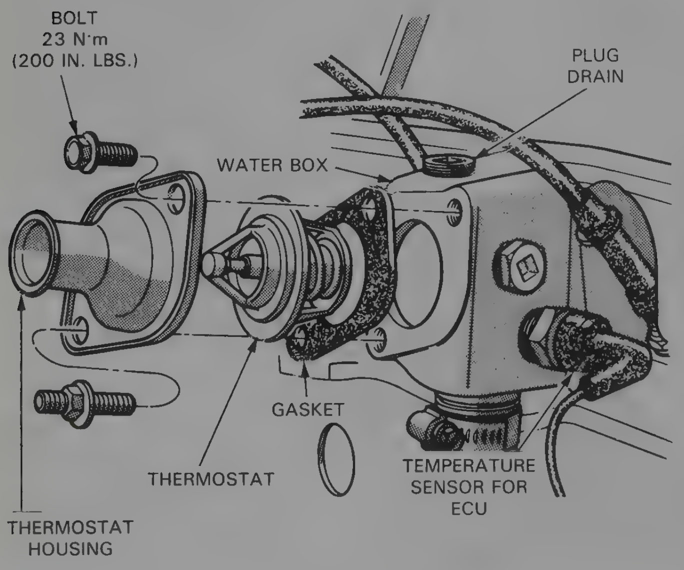


Fig. 19-30. Thermostat setup. Note the coolant temperature sensor, which monitors coolant temperature and sends an electrical signal to the electronic control unit. (Chrysler)

Suspend an ACCURATE thermometer (it must not touch container sides or bottom) in the water. Place the container over a source of heat and gradually raise the temperature of the water. Stir water gently as temperature increases. See Fig. 19-31.

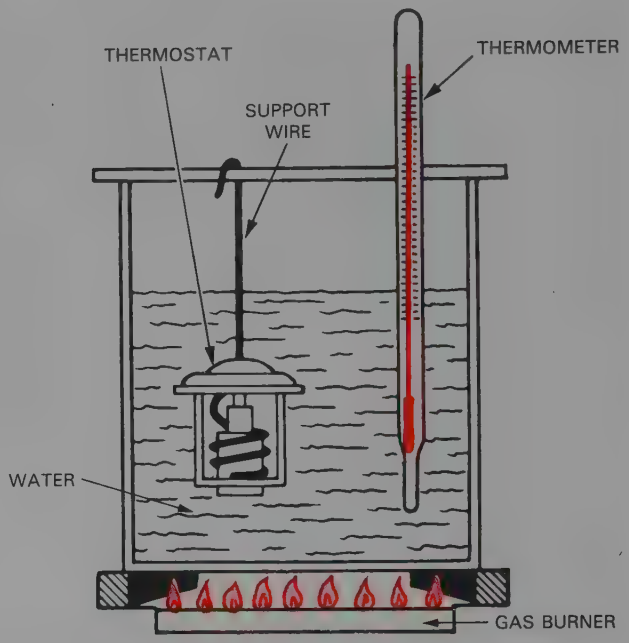


Fig. 19-31. Checking thermostat opening temperature. Note that both thermometer and thermostat are kept free of container sides and bottom.

Watch the valve and as soon as it STARTS TO OPEN, note the temperature. It should be within 5 to 10°F (2.8 to 5.6°C, plus or minus) of the temperature rating stamped on the thermostat.

Continue heating until the valve is FULLY OPENED and note the water temperature. In general, the thermostat should be wide open at a temperature around 20 to 24°F (−6.7 to −4.5°C) above opening temperature.

Discard a thermostat that does not meet specifications. DO NOT TRY TO REPAIR A THERMOSTAT.

SELECTING REPLACEMENT THERMOSTAT

When replacement is necessary, select a thermostat of the correct temperature range. Always use pellet type in a pressurized system. The bellows type thermostat will work only in nonpressurized systems.

If an alcohol base antifreeze will be used (alcohol rarely used—ethylene glycol is commonly used), the thermostat must have a rating of 160°F (71°C) or lower.

Never leave the thermostat out of the engine to try to cure overheating. The thermostat is essential. Use one or more as required.

THERMOSTAT INSTALLATION

Clean out the thermostat pocket and housing. If the system is rusty, it should be cleaned and flushed.

Always install the thermostat so that the pellet (or bellows) will be in contact with the coolant in the engine block. Follow manufacturer's recommendations.

Reversing the thermostat so the pellet faces away from the engine will cause serious overheating. As the block coolant heats up it cannot contact the pellet. The thermostat will remain closed despite block coolant temperature.

When reinstalling the housing, be sure to use an appropriate new seal (gasket and cement, O-ring, RTV sealer). Follow makers recommendations. Replace the housing or cap on some units. Torque housing fasteners to specifications. Fig. 19-32 shows how the pellet side of the thermostat is placed toward the block so it will be touched by the block coolant.

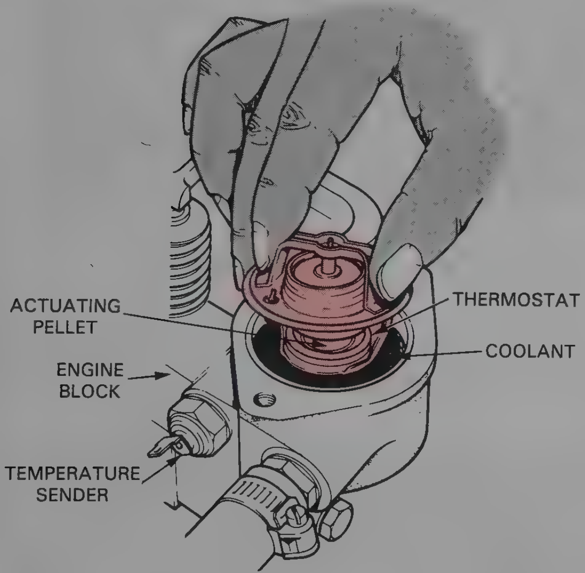


Fig. 19-32. Installing a thermostat. Actuating pellet faces engine block to contact coolant. Note temperature sender. (British-Leyland)

RADIATOR REMOVAL

Drain the system. Remove hoses and oil cooler lines (where used). Remove fan if necessary. Remove radiator support fasteners and carefully remove radiator. Do not dent the cooling fins or tubes.

If the radiator contains a transmission oil cooler, plug the entry holes so that foreign matter cannot enter. Also plug the lines from the transmission.

Store radiator in a spot where it will be protected from physical damage. A typical cross-flow radiator is shown in Fig. 19-33.

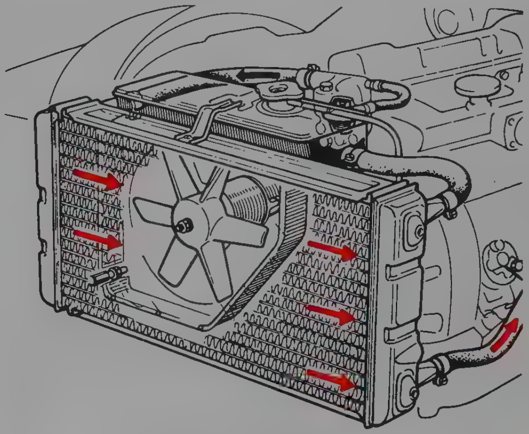


Fig. 19-33. Coolant flow in a cross-flow radiator. (Saab)

FLOW TESTING RADIATOR

To determine the extent of radiator clogging (if any), it may be flow tested. Testing may be done either on or off the car. Flow testing consists of pumping water through the radiator and measuring the flow in gallons (litres) per minute. Flow rate specifications are supplied by equipment manufacturers.

The mechanic in Fig. 19-34 is flow testing a radiator after cleaning and repairing, to make certain it will allow proper circulation.

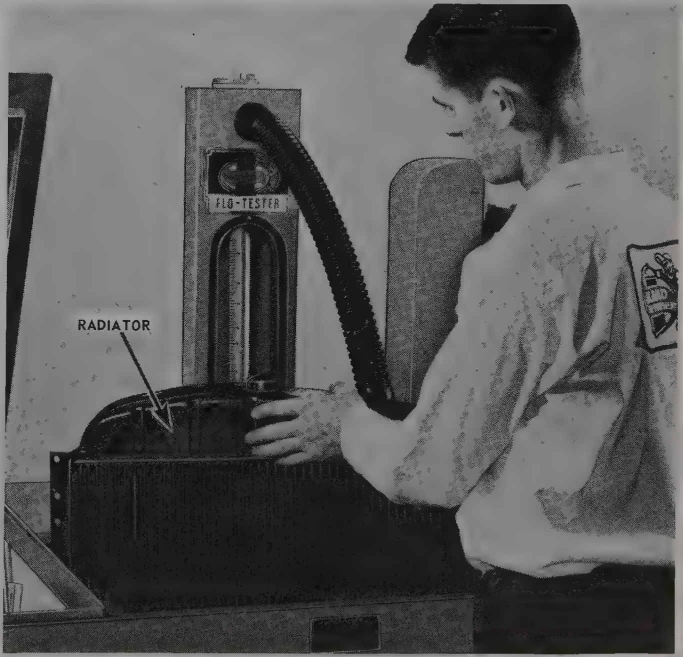


Fig. 19-34. Flow testing a radiator to determine the extent of clogging. (Inland)

RADIATOR CLEANING—OFF THE CAR

The radiator is placed in a special hot cleaning tank and is boiled until all scale, rust, etc., is loosened. The radiator is then removed and thoroughly flushed. Use care with aluminum radiators. Some radiators have the tanks held in place with tabs that are an integral part of the tank plate. O-rings are used to seal in coolant. See Fig. 19-35. If this type of radiator is to be placed in a hot cleaning tank, it should be disassembled to prevent damage to the O-rings. Other radiators have tanks that are made from plastic. Do not place plastic units in hot cleaning solution tanks—disassemble first. The cleaning solution must be compatible with the metal, Fig. 19-36. Instructions supplied by the manufacturer of the cleaning solution should be carefully followed.

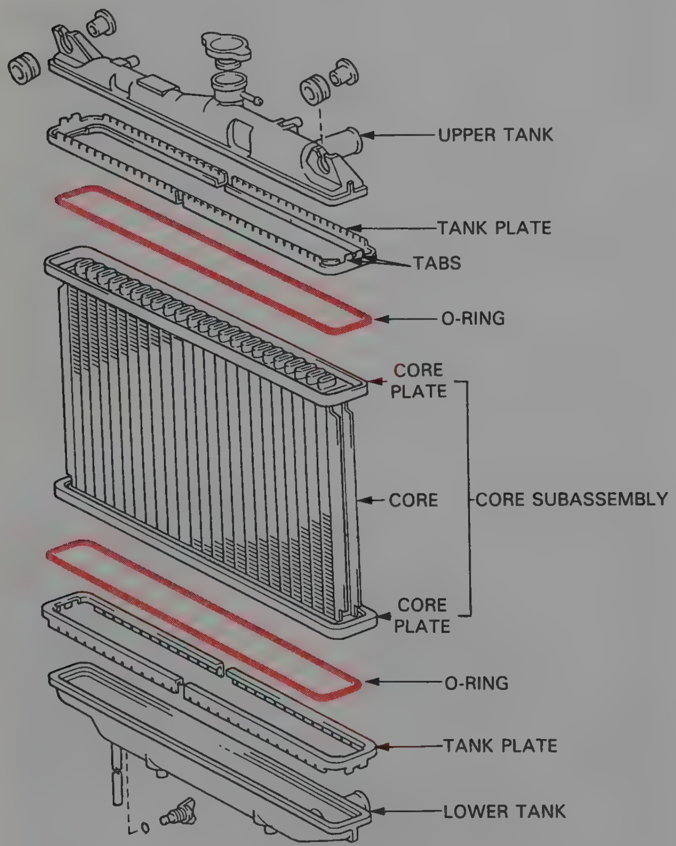


Fig. 19-35. This radiator makes use of O-rings to seal upper and lower tanks, preventing coolant leaks. (Toyota)

TESTING RADIATOR FOR LEAKS—OFF THE CAR

The hose connections are capped off and an air source is attached to the filler neck. The radiator is lowered into a tank of clear water and air pressure (do not exceed pressure cap rating) is applied. Leaks are easily seen. Mark the leaks for repair. See Fig. 19-37.

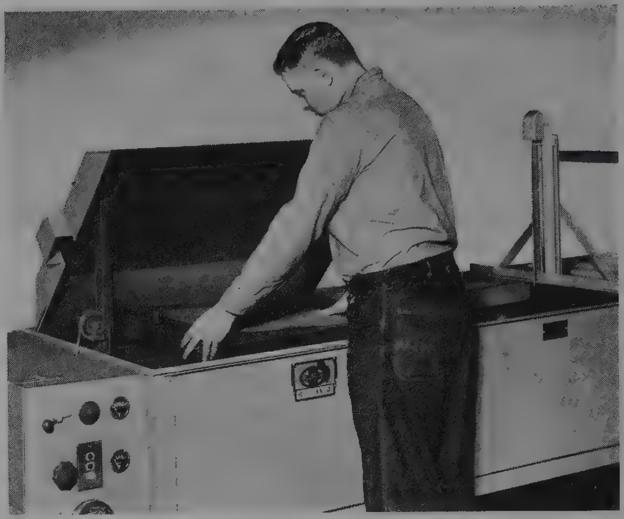


Fig. 19-36. Placing radiator in hot cleaning tank.

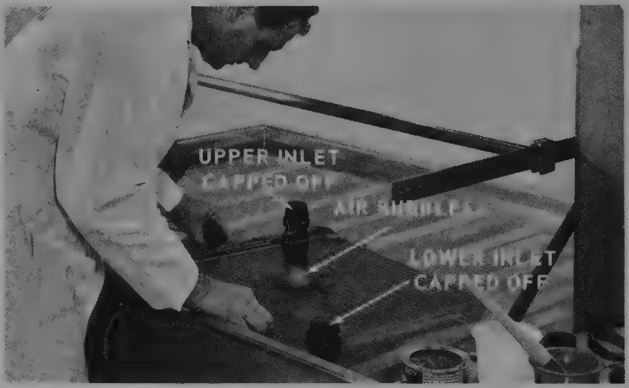


Fig. 19-37. Testing a radiator for leaks. Note how air bubbles pinpoint leakage.

RADIATOR REPAIR

Leaks may be repaired by careful soldering (brass and copper radiators) and in some radiators by replacing O-rings. A handy repair stand is shown in Fig. 19-38. Note the use of a torch. Special repair materials are available for use on aluminum radiators.

Regardless of the material used in radiator construction, any area to be repaired must be thoroughly cleaned. Always test for leaks following repair.

WATER PUMP PROBLEMS

Water pump problems usually concern worn bearings, leaking seals, and worn or broken impellers. The pump illustrated in Fig. 19-39 utilizes the block or the engine front cover to form a housing around the impeller. Construction is typical.

An exploded view of a self-contained water pump (does not need a special recess in block to function) is shown in Fig. 19-40.

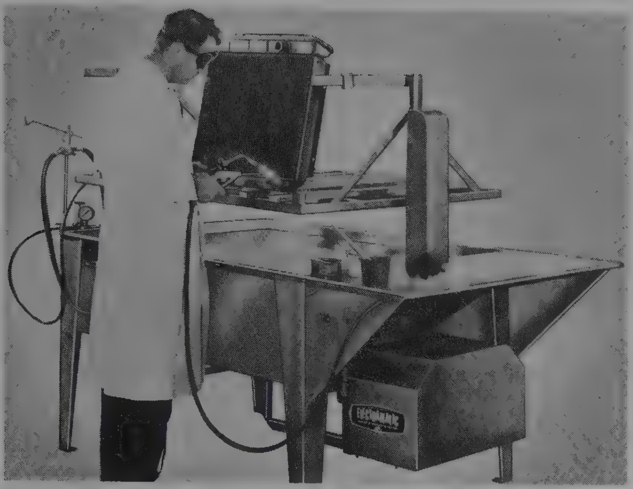


Fig. 19-38. Radiator repair stand. (Inland)

PUMP INSPECTION

Inspect the pump for signs of coolant leakage at the seal drain hole and gasket area. Check for housing cracks.

Loosen the drive belt to remove pressure from the pump bearings. Grasp the hub and attempt to move the shaft up and down. Little or no play should be present. Spin the shaft to detect any bearing roughness.

Internal inspection will require removal and disassembly.

PUMP DISASSEMBLY

Before dismantling the pump, measure the distance from the hub to the housing. Also determine the clearance between the impeller and housing. Write this information down, so the pump may be reassembled with correct tolerances.

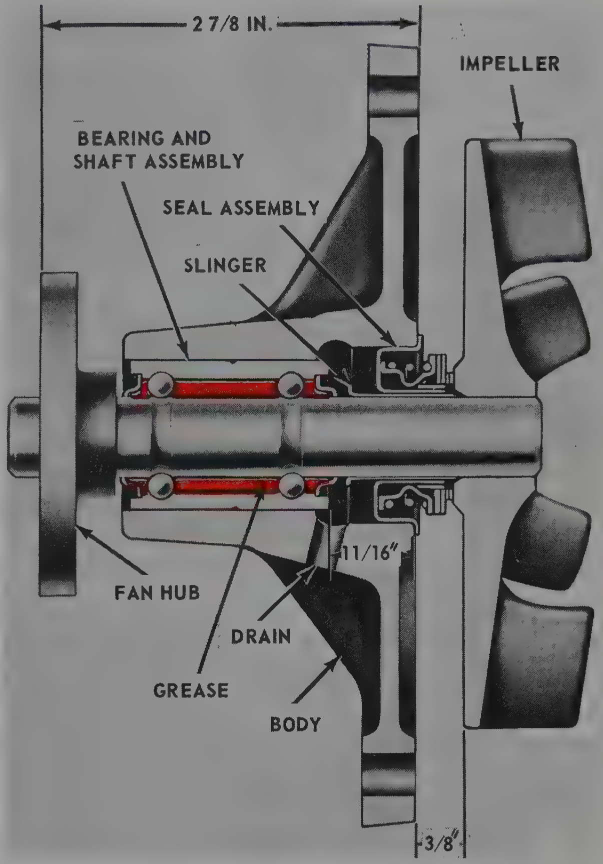

2 7/8 IN.
IMPELLER
BEARING AND SHAFT ASSEMBLY
SEAL ASSEMBLY
SLINGER
11/16"
FAN HUB
DRAIN
GREASE
BODY
3/8"

Fig. 19-39. Typical water pump construction. Bearings are lubricated for their normal service life by sealing in grease. (G.M.C.)

Remove the pump cover plate (where used), fan, and drive pulley. Press off the drive shaft HUB, Fig. 19-41.

Support the pump on blocks to allow the drive shaft, bearing, and impeller assembly to be pressed out. Place

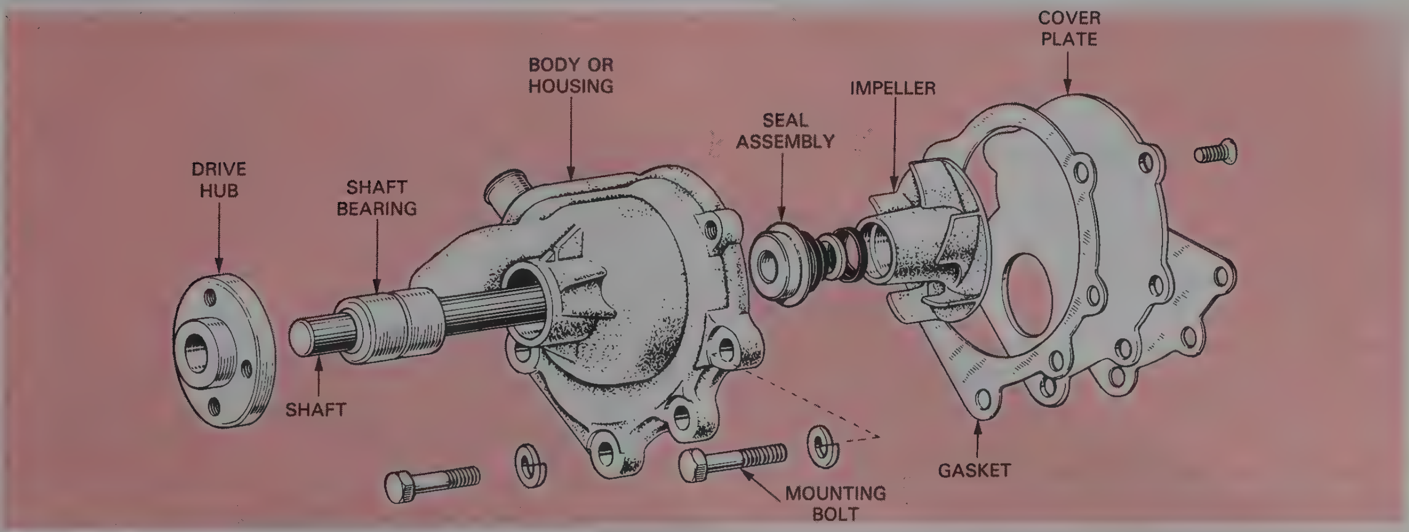

COVER PLATE
BODY OR HOUSING
IMPELLER
SEAL ASSEMBLY
DRIVE HUB
SHAFT BEARING
SHAFT
GASKET
MOUNTING BOLT

Fig. 19-40. Self-contained water pump. Note part names. (Toyota)

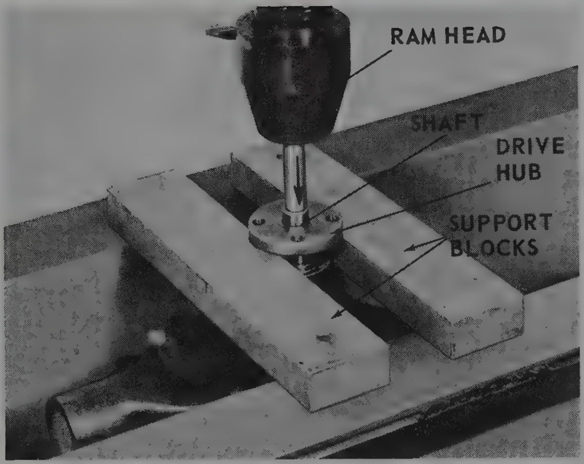


Fig. 19-41. Removing pump drive hub from shaft. (Chevrolet)

blocks as shown in Fig. 19-42. APPLY PRESSURE TO THE BEARING OUTER RACE, NOT TO THE SHAFT. Pressure on the shaft will damage the bearings.

Support the impeller and press from the shaft. Work carefully. Plastic, thin stamped metal, or cast impellers may be broken from the shaft by hammering. Refer to Fig. 19-43.

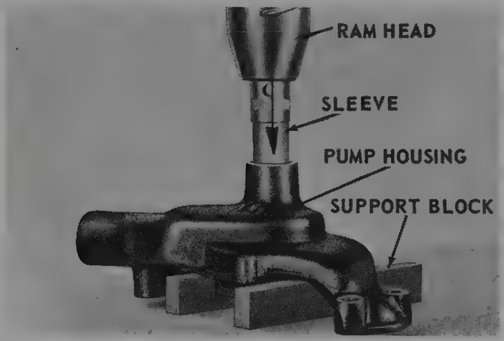


Fig. 19-42. Pressing shaft, bearing, and impeller assembly from pump body. Apply pressure to outer bearing race—NOT TO SHAFT.

Clean all parts. Do not soak shaft and bearing in solvent. This would dilute the grease and probably cause bearing failure.

NOTE: Some pumps cannot be disassembled successfully. In these cases, replace the pump.

PUMP ASSEMBLY

Install a new seal assembly. Before driving into place, coat the edge of the seal cup with gasket cement. Seat in seal cup recess. See Fig. 19-44.

Press the shaft and bearing assembly into place. Apply pressure to the outer bearing race—not to the shaft. Press in to the specified depth. Look at Fig. 19-45.

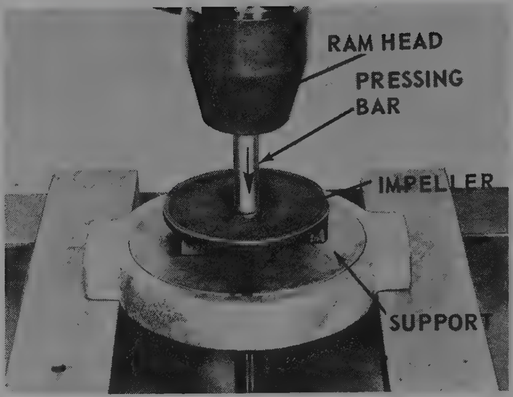


Fig. 19-43. Forcing impeller from pump shaft. Pressing bar must be slightly smaller than shaft.

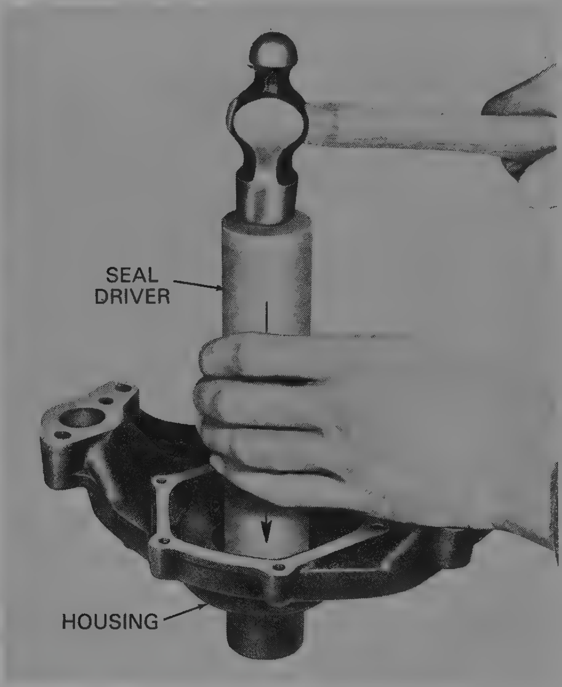


Fig. 19-44. Driving water pump seal into place.

Force the drive hub the correct distance up the shaft (do not put it on backwards). The mechanic in Fig. 19-46 is using a special gauge rod to determine the correct distance.

The impeller is next seated on the shaft. Impeller seal contact surface must be smooth. Press on until specified clearance exists. A feeler gauge is being used to check impeller to housing clearance in Fig. 19-47.

Replace the pump cover (where used). Use gasket cement and new gasket. Some only require the use of a form-in-place gasket material such as RTV (room temperature vulcanizing) silicone. Follow makers recommendations. Assembled pump is shown in Fig.

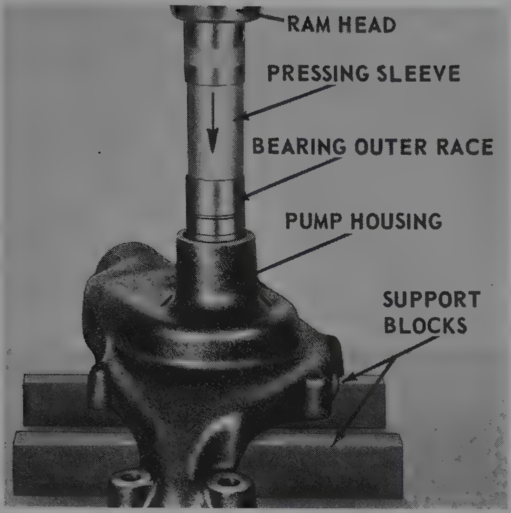


Fig. 19-45. Pressing pump shaft and bearing assembly into housing. Press to depth specified. Apply pressure to bearing outer race.

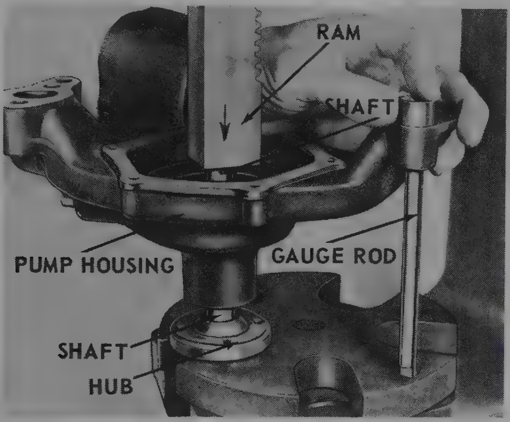


Fig. 19-46. Forcing pump drive hub on shaft. Note use of gauge rod to accurately position hub.

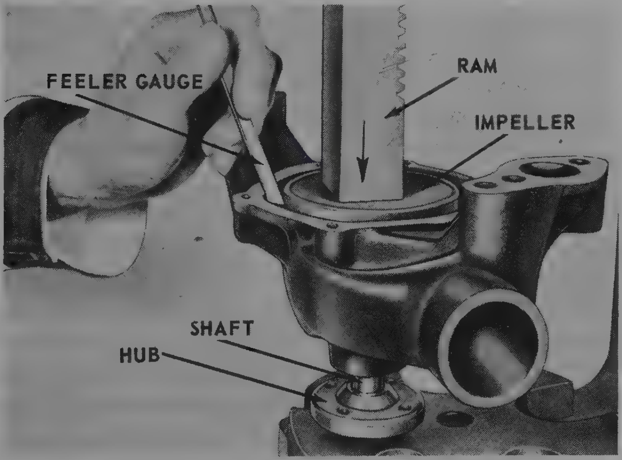


Fig. 19-47. Positioning impeller on shaft. Note use of feeler gauge to check clearance between impeller and housing. Check point for this pump is shown in Fig. 19-48.

19-48. Note critical positioning of the parts in relation to each other. Part positioning specifications vary. Make certain you have the correct specifications.

PUMP INSTALLATION

Use a new gasket or gaskets, cement, O-rings, or use RTV silicone sealer as required. Install the fasteners and tighten EVENLY to the correct torque. Pumps are easily cracked by careless tightening.

Install hose, pulley, spacers, fan, fan belt, and related components. Tension belt.

Sight across the pulleys to make certain the drive hub is positioned to bring the pump pulley in line with the crankshaft drive pulley and any other pulley concerned. Pulley misalignment will cause rapid belt wear.

CORE HOLE PLUG REPAIR

Leaking core hole plugs should be removed. Drive a sharp nosed pry bar through the center of the core hole plug. By prying sideways, the plug should pop out. Another technique involves drilling a small hole in the center of the plug. Punching or drilling near an edge can damage the plug seat ledge in the block. A hook-shaped rod is inserted in the hole and the other end is attached to a slide hammer puller. A few taps and the plug should be out.

Clean the seating area of the plug hole thoroughly. Coat both plug and hole seat with nonhardening sealer and drive the plug into place.

Special tools have been used to seat both cup and expansion type core plugs in Fig. 19-49.

Plugs that are pulled into place and retained by a screw fastener are available. These are handy where driving room is limited.

AIR-COOLED SYSTEM

On air-cooled engines, be sure to check blower fan belt condition and tension. Clean all finned surfaces and make certain all air ducts are free of debris. Check condition of duct air flow control valves and thermostat where used. Shrouding should be in place. Fig. 19-50 illustrates the flow of air in an air cooled system.

SUMMARY

The cooling system, when in good order, is quite efficient. The mechanic should understand the function of all parts of the system.

Inhibitors should be used to prevent rust and corrosion. Some antifreeze solutions include inhibitors and water pump seal lubricant. Always use clean, soft water when filling cooling system.

Denatured alcohol, methanol, and ethylene glycol

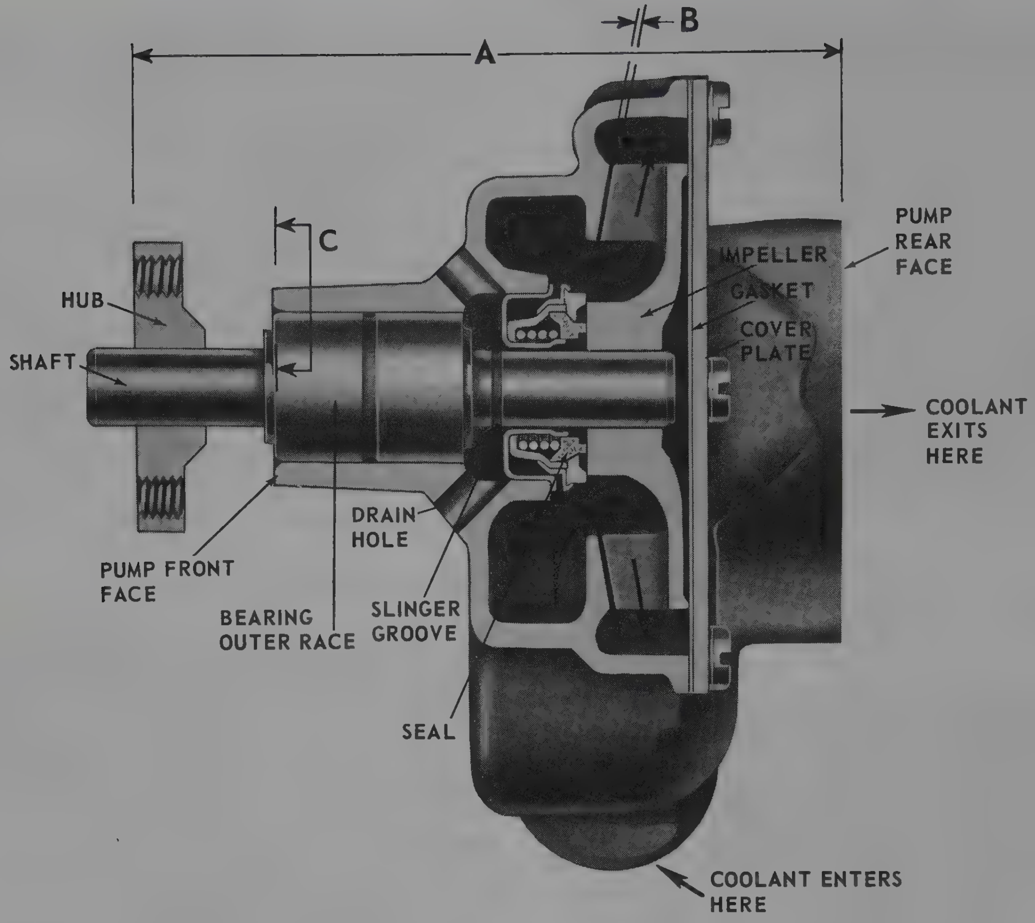


Fig. 19-48. Assembled pump. A—Required distance from hub front face to pump rear face. B—Required clearance between impeller blades and housing. C—Front face of bearing outer race flush with pump front face. Note path of coolant through pump. (Chevrolet)

are three antifreeze solutions. Ethylene glycol is called "permanent" antifreeze and is widely used.

Always drain and flush system before filling with fresh water and antifreeze. Torque heads, tighten hose clamps, and check for leaks.

A special hydrometer may be used to check the strength of the system antifreeze solution.

Moderately contaminated systems may be cleaned by using chemical cleaners, running the engine, and draining. Heavy rusting or scaling requires the use of stronger chemicals and reverse flushing of radiator and block.

In severe cases of radiator clogging, the radiator must be removed and cleaned in a hot tank. In some instances, partial dismantling is required.

Use special care in selecting cleaners for use with an aluminum radiator. Use aluminum pressure caps and aluminum drain cocks on aluminum radiators to prevent electrolysis (creation of an electric current with resulting damage to metal).

Pressure test the system to detect external leaks. Do not exceed pressure stamped on pressure cap. Check while cold and hot. A special tool and fluid can be used to detect combustion leaks in cooling system.

The pressure cap should be tested. Inspect radiator filler neck cap seat and locking cams. Overflow tube must be open.

Use great care when removing a pressure cap while the engine is hot. Never add water to an overheated engine. Allow to cool somewhat. Start engine. Run at fast idle and add water slowly.

Check hose condition. Look for hardening, cracking, swelling, and softening. Tighten hose clamps.

Use nonhardening cement on hose fittings when replacing a hose. Use hose of the correct shape and size. Avoid forcing bends in hose unless of the flexible type.

Check drive belts for proper condition. Cracked, frayed, split, glazed, or oil soaked belts should be replaced. Set belt tension to specifications by using the belt deflection method or belt strand tension gauge.

Fluid drive fans must generally be serviced as a unit, although some models permit replacement of a bimetallic spring or bimetallic strip and operating piston.

Electric motor driven fans are used on some installations. They are controlled by coolant temperature sen-

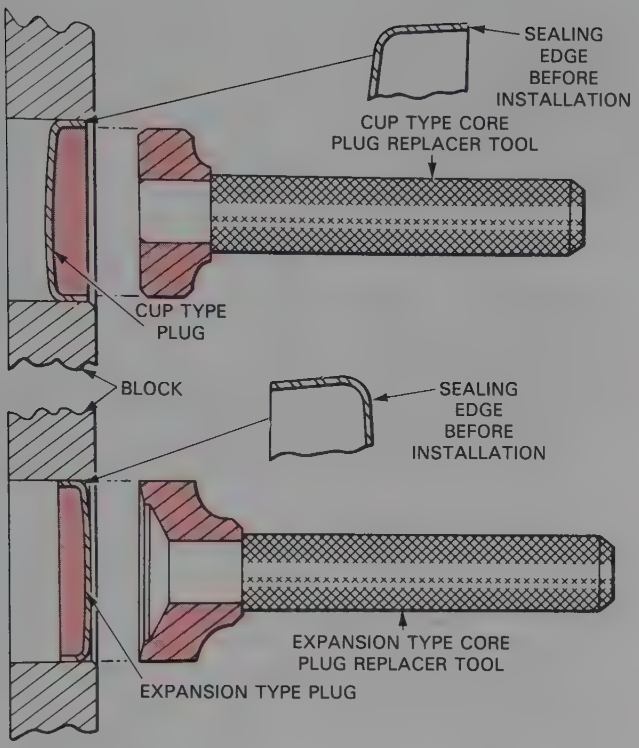

SEALING EDGE BEFORE INSTALLATION
CUP TYPE CORE PLUG REPLACER TOOL
CUP TYPE PLUG
BLOCK
SEALING EDGE BEFORE INSTALLATION
EXPANSION TYPE CORE PLUG REPLACER TOOL
EXPANSION TYPE PLUG

Fig. 19-49. This illustrates two typical core plug installation tools. These are not interchangeable. If wrong tool or core plug is used, a damaging leak or plug "blow out" could occur. (Ford)

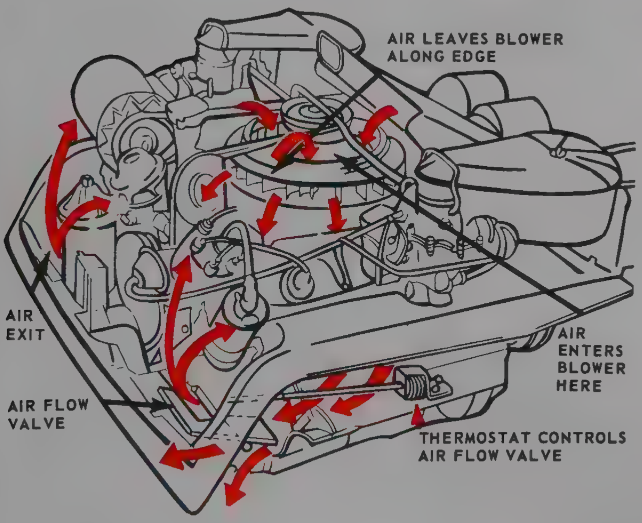

AIR LEAVES BLOWER ALONG EDGE
AIR EXIT
AIR ENTERS BLOWER HERE
AIR FLOW VALVE
THERMOSTAT CONTROLS AIR FLOW VALVE

Fig. 19-50. One type of air cooling system. Note air flow and use of thermostat to control duct air flow valve. (Harrison Radiator)

sors. Motors are generally not serviceable and should be replaced with a new unit.

Never try to straighten, weld, or glue damaged fan blades.

Always remove ground clamp from battery before working on water pump, fan, radiator, hoses, or belts.

Test thermostats for condition and for initial opening and full opening temperature points. Never use a bellows thermostat in a pressurized system. The pressurized system requires a PELLET THERMOSTAT. Install thermostats with the actuating unit (pellet or bellows) facing toward the engine so that the unit will be contacted by the coolant in the block.

Radiators can be flow tested to determine extent of clogging. Bench cleaning, testing, and repair of radiators are required in some instances.

Many water pumps can be rebuilt. When rebuilding, assemble so that part positioning is correct. Use care when installing new core hole plugs.

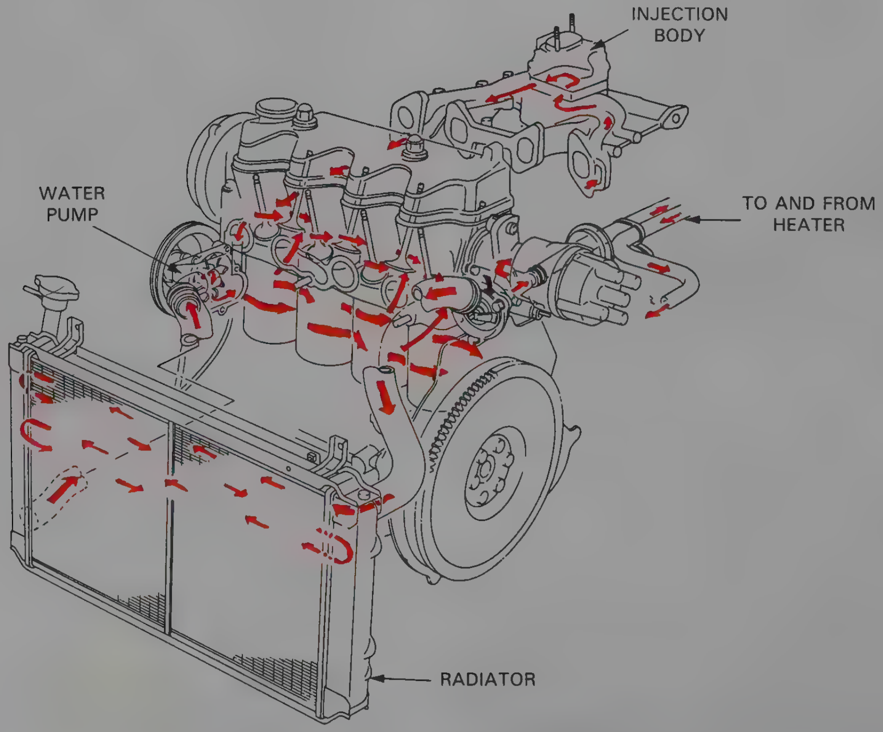
KNOW THESE TERMS

Soft water, Antifreeze, Ethylene glycol, Hydrometer, Neutralize, Reverse flushing, Pressure tester, Pressure pump, Thermostat, Radiator, Pressure cap, Sea level, Belt tension, Fluid drive fan, Impeller, Core hole plug, Aeration, Closed cooling system, Cooling system scale.

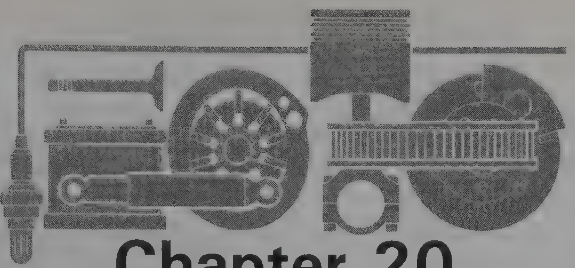
QUIZ—Chapter 19

1. Cooling systems must be protected from rust and corrosion by using:
   a. Clean, soft water.
   b. Inhibitors.
   c. Alcohol antifreeze.
   d. A 15 psi (103 kPa) pressure cap.
2. Scale deposits can be minimized by using __________, __________ water.
3. Ethylene glycol antifreeze often contains inhibitors, stop leak, and water pump lubricant. True or False?
4. Name three types of antifreeze.
5. __________ and __________ __________ antifreeze both have a low boiling point.
6. __________ __________ is referred to as permanent antifreeze.
7. When an alcohol base antifreeze is used, the thermostat temperature rating should not exceed:
   a. 180 °F (82 °C).
   b. 160 °F (71 °C).
   c. 140 °F (60 °C).
   d. 190 °F (88 °C).
8. Ethylene glycol is poisonous. True or False?
9. Briefly describe the correct procedure for installing antifreeze in the cooling system.
10. It is best to reverse flush the radiator and block separately. True or False?
11. Always reverse flush the car heater. True or False?
12. When reverse flushing, the thermostat should be:
    a. In place.
    b. Removed.
    c. Installed upside down.
    d. Wired to prevent opening.

13. During the cooling system cleaning process, the heater control should be set to the ________ ________ position.
14. When pressure testing the cooling system, limit the maximum pressure to that stamped on the ________ ________.
15. Combustion leaks can be detected only by removing the cylinder heads for a visual inspection. True or False?
16. Ethylene glycol, if it leaks into the cylinders, can clog rings, bearings, and other parts. True or False?
17. A pressure cap should be pressure tested periodically. True or False?
18. The pressure cap should be tested to a pressure approximately 10 psi (69 kPa) above its rating. True or False?
19. Always use an ________ pressure cap and an ________ drain cock on an aluminum radiator.
20. What two important areas of the radiator filler neck should be checked?
21. Completely removing a pressure cap when an engine is hot can cause:
    a. Cracked block.
    b. Warped valves.
    c. Sudden, violent flash of steam.
    d. Bulged radiator.
22. Name three hose conditions that require replacement to correct.
23. When installing radiator hose, always use ________ ________ to insure a water tight connection.
24. List three drive belt conditions that require replacement.
25. Describe three methods of belt tensioning.
26. Before working on fans, water pumps, or V-belts, always disconnect the ________ ________ ________.
27. Thermostats should be tested for both ________ opening and ________ open temperature points.
28. Always use a pellet type thermostat in a pressurized cooling system.
29. Install a thermostat so that the pellet or bellows contacts the coolant in the engine. True or False?
30. When an engine has been overheating, it is good practice to leave the thermostat out of the system. True or False?
31. The extent of radiator clogging can best be checked by:
    a. Reverse flushing.
    b. Looking in the filler neck.
    c. Draining and checking coolant color.
    d. Flow testing.
32. List three possible water pump problems.
33. All pumps can be repaired. True or False?
34. Describe the procedure involved in a core hole plug replacement.
35. Instead of using a V-belt, some vehicles use an ________ ________ to drive the cooling fan.
36. Some thermostats can be removed by simply taking off their housing cap by hand. True or False?



Overall cooling system operation. (Nissan)



Chapter 20

FUEL SYSTEM SERVICE—FUEL DELIVERY

After studying this chapter, you will be able to:

☐ Describe the cleaning, removal, repair, and replacement of fuel tanks.
☐ Clean, repair, and install fuel lines.
☐ Test, remove, repair, and replace fuel pumps.
☐ Service fuel filters.
☐ Explain vapor lock.
☐ List the safety rules involved in fuel delivery system service.

In this chapter, we will discuss the servicing of units of the fuel system including the fuel tank, fuel line, fuel pump, and filter. This will prepare you for later chapters on carburetors and injection.

FUEL TANK

A typical fuel tank, along with related components, is shown in Fig. 20-1. This tank is made of steel.

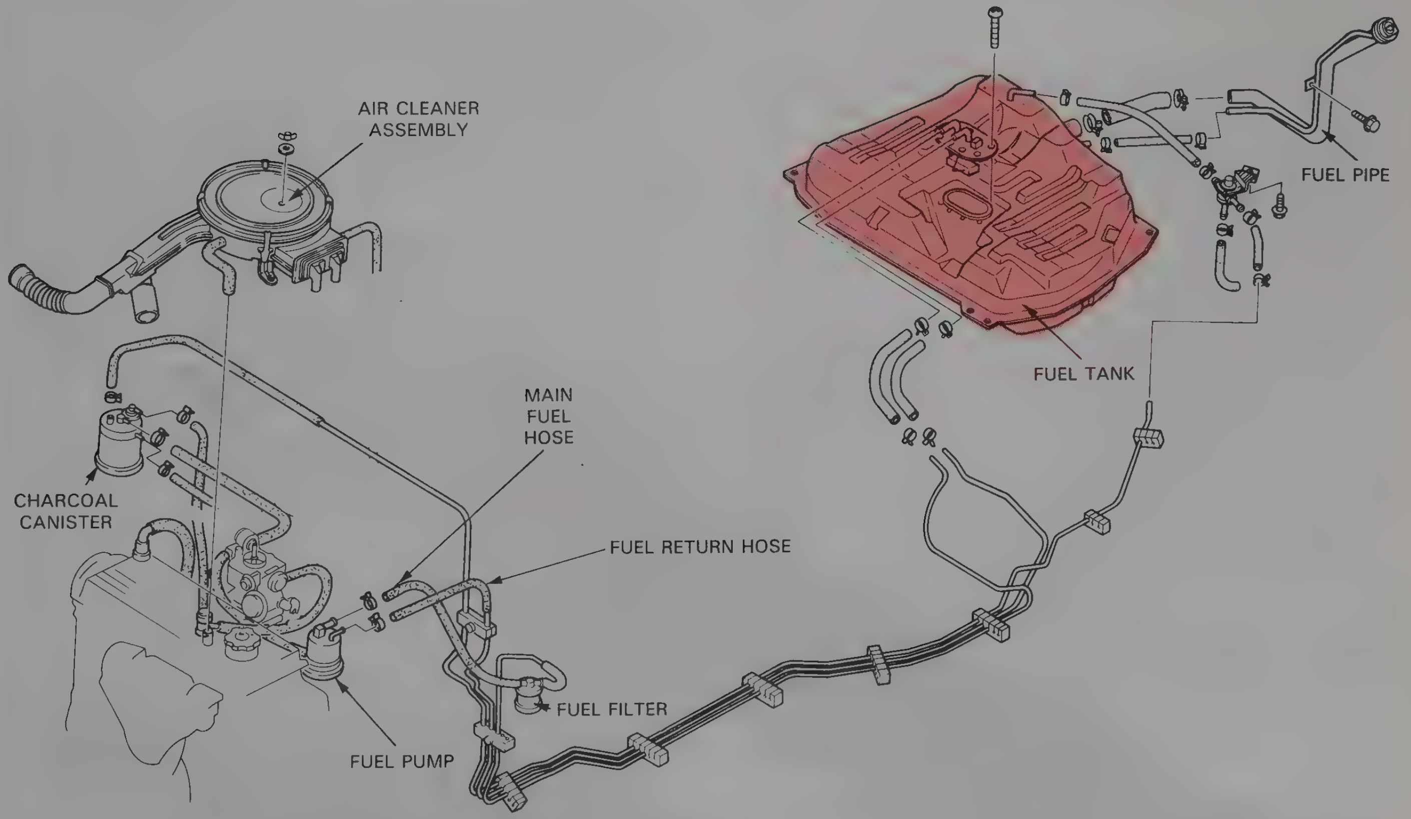

AIR CLEANER ASSEMBLY
MAIN FUEL HOSE
CHARCOAL CANISTER
FUEL RETURN HOSE
FUEL FILTER
FUEL PUMP
FUEL PIPE
FUEL TANK

Fig. 20-1. This fuel tank is constructed of steel. Note the related components. (Mazda)

Some tanks are made of plastic such as polyethylene.

A fuel tank that is contaminated with excessive quantities of water or dirt should be removed for cleaning. Drain the fuel tank by opening the tank drain, Fig. 20-2. If no drain is provided, fuel in the tank may be removed by siphoning. A handy siphoning device is assembled from a length of 3/8 in. ID hose. A tapered slit is cut about 18 in. (457 mm) from one end. A pipe nipple is installed in the other end of the hose. In use, the end of the hose with the nipple is run into the tank until it strikes the bottom. The free end of the hose is placed below the level of the tank. An air gun is inserted into the slit and a short blast of air is admitted. This will create a vacuum and start the flow of the fuel through the siphon.

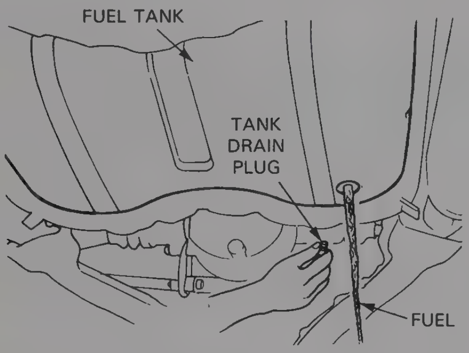


Fig. 20-2. Some fuel tanks have a drain plug. (Mazda)

Another way to start a siphon is to use two separate lengths of hose. Insert one end of both pieces of hose into the fuel tank. Jam a rag into the filler neck to form a seal around the two pieces of hose. Cover external vents with masking tape. Blowing air into one hose will create pressure in the tank and siphon action will be started in the other hose. Do not start the siphoning action by sucking on the hose.

The two siphoning techniques just mentioned should be used only when no commercial siphoning tool is available. They must be used very carefully to reduce the danger of fire.

Whenever possible, a siphoning tool such as shown in Fig. 20-3 should be used. This tool is equipped with a fuel pump, filter, and storage tank.

REGARDLESS OF THE SIPHONING TECHNIQUE USED, WHEN WORKING WITH GASOLINE OR DIESEL FUEL, BE CAREFUL OF FIRE. PLACE GASOLINE OR DIESEL FUEL IN CLOSED, PROPERLY DESIGNED CONTAINERS!

Remove the battery ground strap to prevent possibility of shorting the tank sender wire (part of fuel gauge assembly).

Disconnect the fuel line or lines and cover ends with masking tape. Disconnect filler pipe and any external vents. Remove tank support straps and lower tank.

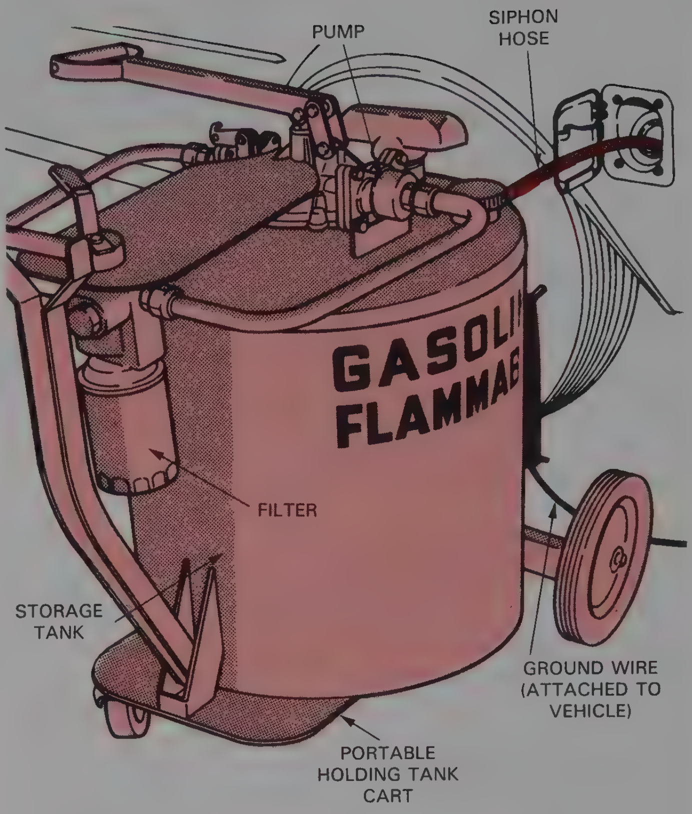


Fig. 20-3. Portable fuel storage tank. This unit can drain and then refill the tank. Note ground wire. (Chrysler)

REMOVE SENDER GAUGE AND PICKUP ASSEMBLY

Remove the fuel gauge sender assembly. Do not bend the float arm or the pickup pipe. See Figs. 20-4 and 20-5.

Tilt tank and drain out any remaining gasoline or diesel fuel. Inspect the tank interior. If rusted, replace. If not, proceed with cleaning.

Place a quart or so of clean gasoline in the tank. While holding a rag over the filler neck and sender hole, "slosh" around vigorously. Drain. Repeat process. Blow tank dry with compressed air and inspect. Stubborn dirt may require cleaning the tank interior with steam.

REMEMBER THAT AN EMPTY OR PARTIALLY EMPTY FUEL TANK WILL CONTAIN VAPORS. IF IGNITED, THESE VAPORS WILL PRODUCE A VIOLENT EXPLOSION! DON'T TAKE CHANCES. AVOID GETTING FUEL ON YOUR CLOTHING.

Clean the pickup pipe and filter by directing a gentle blast of air down through the pickup pipe. Blow until clean. If badly clogged, replace the pickup filter.

Replace sender unit. Use a new gasket and gasket cement. Install tank.

If the tank uses a nonvented (airtight) cap, make certain the vent tube is open.

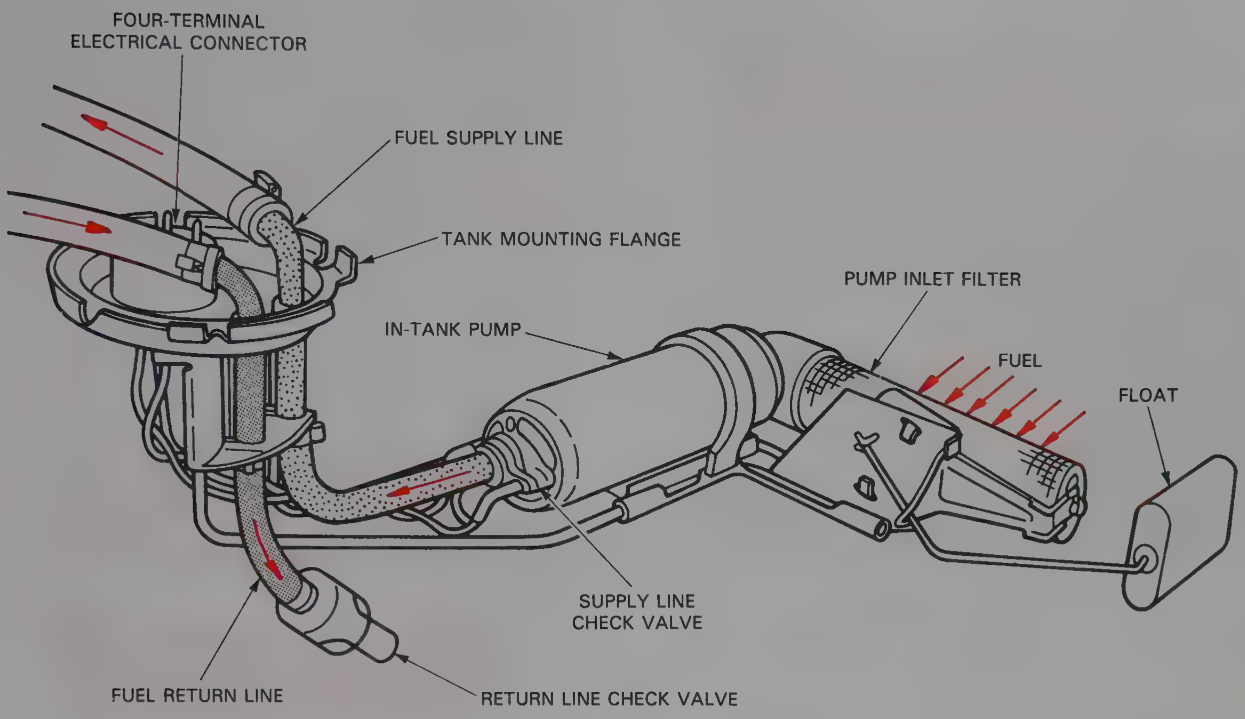


Fig. 20-4. Fuel tank pickup pipe, filter, float, and return pipe combined in one unit. Note fuel return line. (Chrysler)

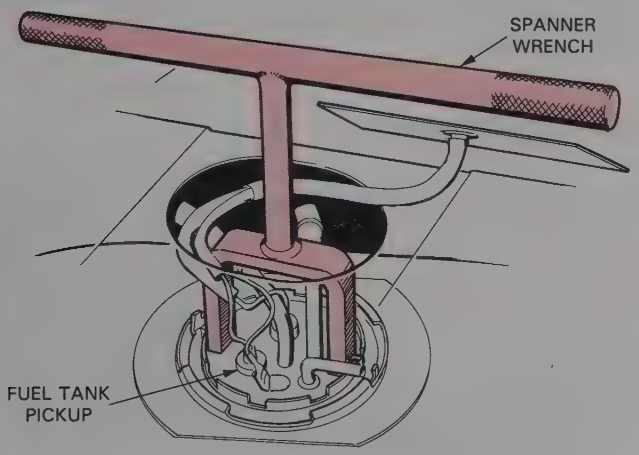


Fig. 20-5. Using a special spanner type tool to remove fuel tank pickup unit. Disconnect battery before removing pickup! (Volvo)

Torque tank retaining strap bolts. Be careful not to overtighten. Make sure insulation strips are in place.

TANK REPAIR SAFETY MEASURES

A leaking metal fuel tank may be repaired by soldering or brazing but ONLY AFTER ADEQUATE SAFEGUARDS HAVE BEEN TAKEN.

The fuel tank should be THOROUGHLY STEAM CLEANED INSIDE AND OUT.

Following thorough cleaning, the tank should either be filled with an inert (nonexplosive) gas such as carbon dioxide or nitrogen, or COMPLETELY FILLED WITH WATER.

Another method is to steam clean as recommended and then to place a quart of carbon tetrachloride in the tank. Slosh vigorously. Without draining the carbon tetrachloride, place an air hose in the tank. Admit a heavy and continuous stream of air. Place a fan in position to blow the carbon tetrachloride fumes away from the tank. CARBON TETRACHLORIDE FUMES ARE TOXIC—ESPECIALLY WHEN HEATED—DO NOT BREATHE THEM. The air flow in the tank must be continuous and strong during the entire soldering or brazing operation. See Fig. 20-6.

REMEMBER THAT FUEL TANKS CAN BE LETHAL BOMBS CAPABLE OF INSTANTLY KILLING ANYONE NEARBY. USE UTMOST CARE IN ALL TANK CLEANING AND REPAIR PROCEDURES.

Have a fire extinguisher handy and keep other persons away from the operation.

NOTE: The foregoing techniques for fuel tank repair apply only to automobile fuel tanks. Heavy steel tanks, high pressure containers, grease and oil drums require additional safeguards and, in some instances, somewhat different techniques.

Test repair by covering with wet soap lather. Place an air hose in tank and admit air. By holding a rag around hose where it enters, a mild pressure will be built up. If the repair is sound, bubbles will not appear.

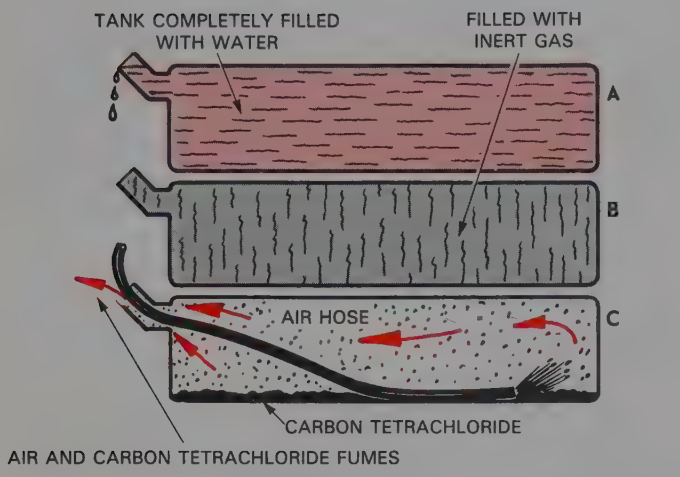

TANK COMPLETELY FILLED WITH WATER
FILLED WITH INERT GAS
A
B
AIR HOSE
C
CARBON TETRACHLORIDE
AIR AND CARBON TETRACHLORIDE FUMES

Fig. 20-6. Solder or braze only after thorough stem cleaning and preparing the tank as shown in either A, B, or C.

Place a quart of fuel in the tank, slosh around and pour out. Blow tank dry and install in car.

COLD PATCHING REPAIRS

There are various epoxy type sealants and special patching cloth that can be used to repair both metal and plastic tanks. These work very well for some applications if done properly. Follow manufacturer's recommendations.

Regardless of the type of repair chosen, remember that fuel tank integrity is vitally important. Even small leaks can cause disastrous fires. Do your work carefully. If there is any doubt, replace the tank.

EXPANDED (BULGED) FUEL TANK

Fuel tanks can become expanded from excessive in-tank pressure. This can cause fuel leaks and tank damage.

In the modern sealed fuel system, considerable in-tank pressure can be generated by such items as a defective fuel cap, vapor canister filter plugged, or pinched or clogged vapor lines. Whenever a bulged tank is encountered, check the system and clean, repair, or replace any item responsible. Check tank for possible damage.

Following repairs, make certain the excess pressure condition is no longer present. In many systems, the pressure relief valve in the filler cap should open at around 1 1/2 to 2 psi (10 to 17 kPa).

REMOVING DENT IN FUEL TANK

Occasionally, the bottom of a fuel tank is shoved inward by striking some object. The tank can often be straightened by removing the tank from the car and completely filling it with water. Plug the vent tube and place a nonvented cap on the filler neck. Admit air through the pickup tube. Air exerts pressure on the water and will usually cause the dented area to bulge outward. In doing this, be sure to admit only enough pressure to pop the dent out. ALWAYS FILL THE TANK WITH WATER BEFORE APPLYING AIR PRESSURE. THE USE OF AIR ALONE CAN CAUSE THE TANK TO RUPTURE AND FLY APART IN A DANGEROUS FASHION. See Fig. 20-7.

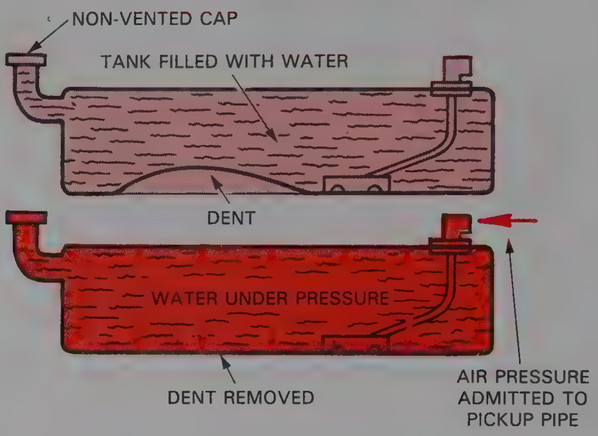


Fig. 20-7. Removing a dent in a fuel tank by filling with water and admitting low air pressure.

FUEL LINE CLEANING

Disconnect the fuel line at the tank and at the fuel pump. CAUTION: FUEL SUPPLY LINES ON FUEL INJECTION SYSTEMS CAN MAINTAIN CONSIDERABLE PRESSURE FOR SOME TIME AFTER ENGINE IS STOPPED. A special pressure relief valve is often provided to relieve system pressure. If so equipped, use valve following manufacturer's directions. Where no provision is made for pressure relief, loosen connections SLOWLY and use an absorbent cloth to contain any spill.

Some electric pumps are in the fuel tank. In these cases, disconnect the line from the carburetor or filter, whichever the line comes to first.

Direct an air blast from the fuel pump and toward the gas tank. Blow until clean. If line remains restricted, check for a dented or kinked spot.

If the tank is removed for cleaning, clean the fuel line also. Blow out the line from the carburetor to the pump. Remove any in-line filter before applying pressure. Replace with a new filter, Fig. 20-8.

REPAIRING DAMAGED FUEL LINE

Other than the flex hose from the fuel pump to the fuel line, the fuel line rarely needs repair. If dented,

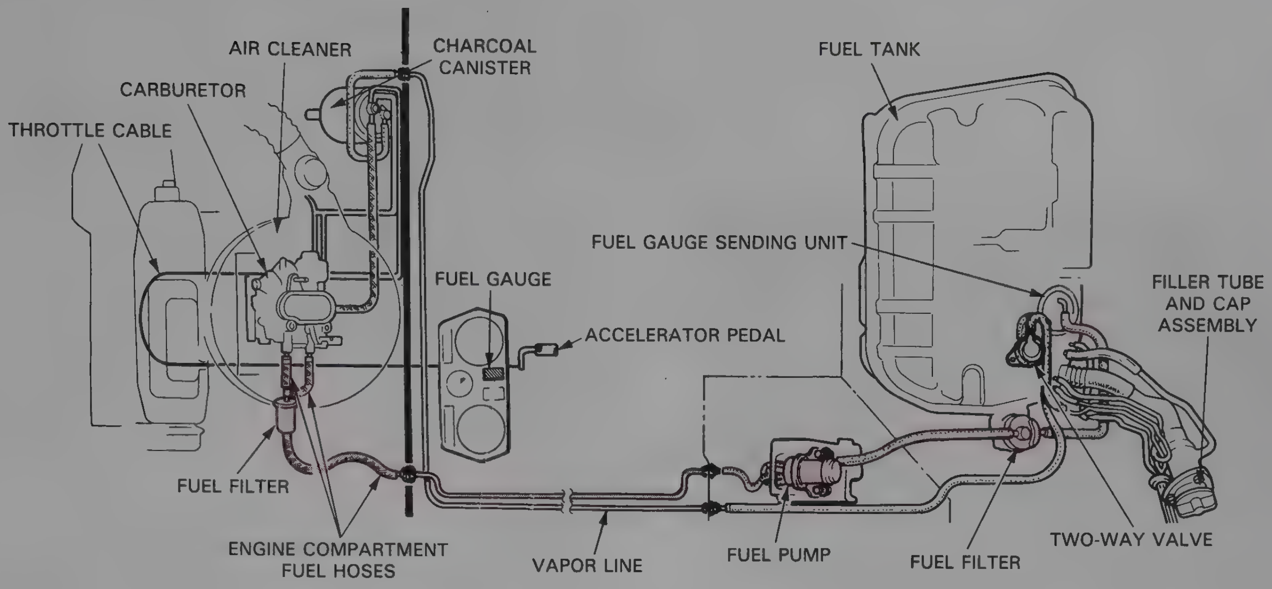

AIR CLEANER
CHARCOAL CANISTER
FUEL TANK
CARBURETOR
THROTTLE CABLE
FUEL GAUGE SENDING UNIT
FILLER TUBE AND CAP ASSEMBLY
FUEL GAUGE
ACCELERATOR PEDAL
FUEL FILTER
ENGINE COMPARTMENT FUEL HOSES
VAPOR LINE
FUEL PUMP
FUEL FILTER
TWO-WAY VALVE

Fig. 20-8. Typical fuel line setup from tank to carburetor. (Honda)

severed, or corroded, the damaged section can be removed and replaced with a new section of tubing. Hose can also be used. Make sure joining connections are TIGHT! Refer to Chapter 5 on tubing and hose for full instructions.

TESTING FUEL PUMP

As part of a thorough tune-up, or when carburetion difficulties exist, the fuel pump should be checked for leaks, output pressure, flow volume, and inlet vacuum.

Before testing the pump, tighten the pump diaphragm and mounting screws. Inspect lines for kinks, dents, and leaks. Make sure there is ample fuel in the tank. Clean or replace fuel filters. Check tank vent. Tighten filter bowl and pulsator cover.

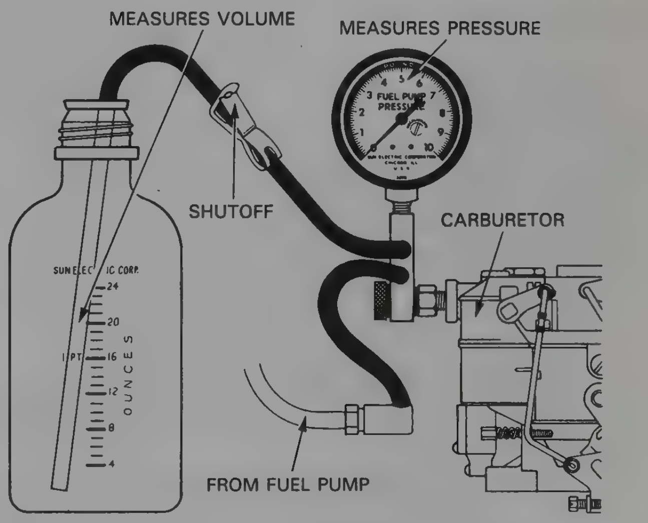

MEASURES VOLUME
MEASURES PRESSURE
FUEL PUMP PRESSURE
SHUTOFF
CARBURETOR
SUN ELECTRIC CORP.
24
20
1 PT
16
12
8
4
OUNCES
FROM FUEL PUMP

Fig. 20-9. Setup for checking fuel pump pressure and volume. (Sun Electric)

PUMP PRESSURE TEST

Disconnect the fuel line at the carburetor. Install a suitable pressure tester. The tester illustrated in Fig. 20-9 handles both pressure and volume tests. Regardless of the tester used, the gauge should be held at or near carburetor level, but not more than 6 in. (152 mm) above or below to prevent false readings.

Some manufacturers specify pump pressure at CRANKING SPEEDS, others at RUNNING SPEEDS. If using a tester similar to that in Fig. 20-9, place the flow volume hose in the container and pinch off the hose before starting the engine. With the engine idling at 500 rpm, open the hose shutoff and draw off about 4 oz. (118 mL) of fuel. This will vent the pump, thus removing any trapped air that could cause a false reading.

Stop the engine and dispose of the fuel in the container. When empty, replace the hose and start the engine. While idling at 500 rpm, note the pressure on the gauge. Average pressure will be from 4 to 6 psi (28 to 41 kPa) and will be relatively constant.

Stop the engine. The pressure should either remain constant or fall SLOWLY. A rapid loss of pressure indicates a faulty pump outlet valve or a leaky carburetor float valve. Check fittings too.

A different setup used to check pump STATIC (not supplying fuel to carburetor, hence no fuel flow) pressure is shown in Fig. 20-10. Note that the pressure tester is attached directly to the end of the pressure line. The engine is operated on the fuel remaining in the fuel bowl. The tester is held at carburetor level.

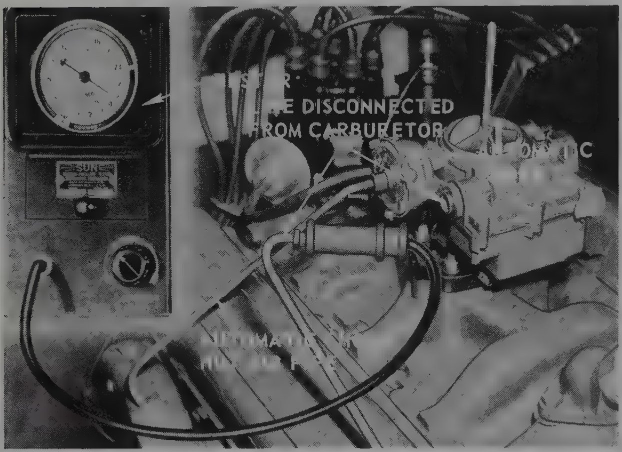


Fig. 20-10. Checking pump static pressure.

PUMP VOLUME TEST

If using a setup as shown in Fig. 20-9, open the fuel flow line shutoff with the engine idling at 500 rpm. Note the exact time (in seconds) the shutoff was opened. As soon as there is around 4 oz. (118 mL) of fuel in the container, shove the tube into the fuel. Watch for bubbles that would indicate an air leak in the intake line. As soon as exactly one pint (16 oz. or 473 mL) has been drawn, note the time in seconds. Close the flow shutoff and stop the engine.

Manufacturer's specifications will generally call for a flow equivalent to one quart in one minute at 500 rpm. See Fig. 20-11.

CAUTION: Use extreme care when conducting both pressure and volume tests. A fuel pump can spray fuel a long distance. Make certain all connections are tight and that the volume hose is in the container. Container should be of glass or clear plastic.

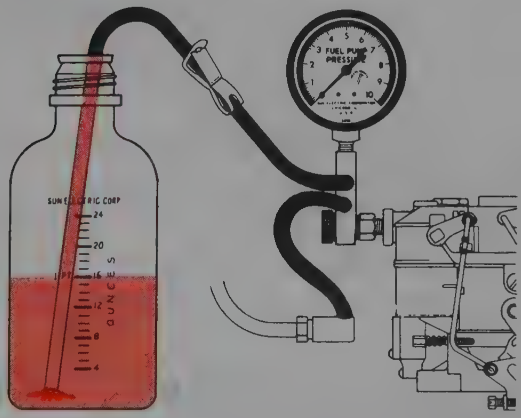


Fig. 20-11. Checking fuel pump volume.

When taking pressure tests on a fuel pump equipped with a vapor return or discharge valve (on air conditioned cars), it is important that the valve be closed. Look at Fig. 20-12. An open valve will give faulty readings. Start the engine and remove the return line at the valve. Hold a can under the valve outlet to catch any gas being discharged. A very small amount of fuel discharge of about 2 1/2 oz. (74 mL) per minute is normal and indicates the valve is closed. Fuel discharge in appreciable amounts indicates the vapor valve is either open from heat or is stuck open. In the case of heat, cool the pump with wet rags. If it is stuck, clean or replace.

ADDITIONAL TEST WHEN PRESSURE OR VOLUME DOES NOT MEET SPECIFICATIONS

When volume or pressure do not meet specifications, the pump inlet vacuum should be determined before condemning the fuel pump. If the vacuum line (line from tank pickup tube to pump) is restricted or leaking air, the pump cannot be expected to perform as required.

PUMP INLET VACUUM TEST

Disconnect the fuel line from the pump inlet flex line. Attach the vacuum gauge to the flex line. IF GAS DRIPS FROM THE OPEN FUEL LINE, CAP IT OFF. Disconnect the pressure line from pump to carburetor at the carburetor. Attach hose to line end and place in a container.

Start the engine and allow to idle until gauge reads highest vacuum. In general, a minimum vacuum reading of 10 in. (34 kPa) should be obtained. When the engine is stopped, the reading should hold steady. A reading of 10 in. (34 kPa) or more indicates the pump valves, diaphragm, flex line, and bowl gasket (where used) are airtight. See Fig. 20-13.

If the reading is below specs or if the vacuum falls off rapidly when engine is stopped, remove the flex line and attach the gauge directly to the pump. If low reading or fall off continues, the pump is defective. If reading is now normal, the flex hose was leaking.

When the vacuum test indicates the pump and flex line are not leaking, test the entire inlet system by removing the line from the fuel tank and attaching the vacuum gauge at this point. Connect the flex line to the fuel line and operate engine. If the vacuum reading drops below specifications, or if it falls off rapidly, and air leak in the inlet system is indicated.

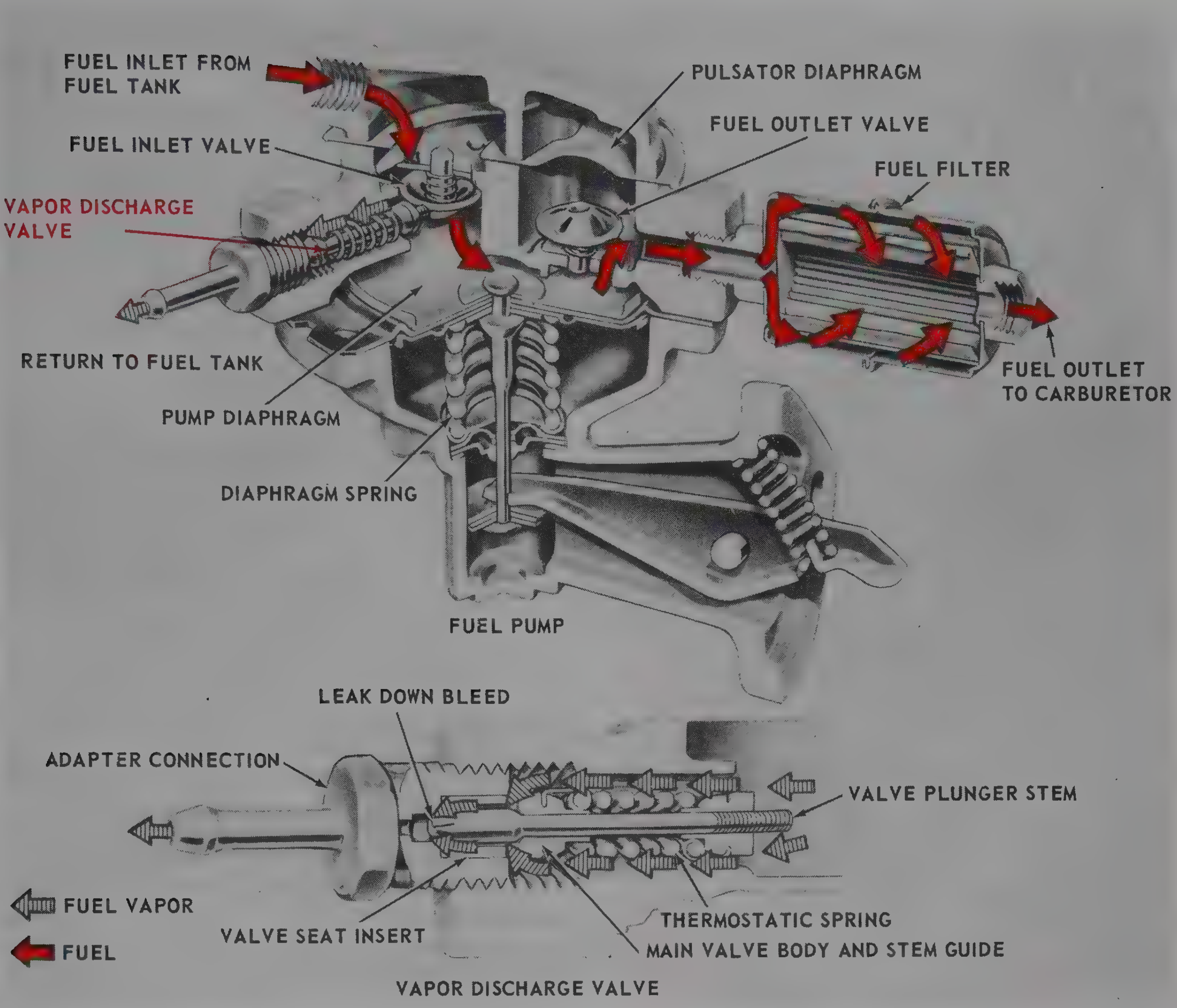

FUEL INLET FROM FUEL TANK
PULSATOR DIAPHRAGM
FUEL OUTLET VALVE
FUEL INLET VALVE
FUEL FILTER
VAPOR DISCHARGE VALVE
RETURN TO FUEL TANK
FUEL OUTLET TO CARBURETOR
PUMP DIAPHRAGM
DIAPHRAGM SPRING
FUEL PUMP
LEAK DOWN BLEED
ADAPTER CONNECTION
VALVE PLUNGER STEM
FUEL VAPOR
FUEL
VALVE SEAT INSERT
THERMOSTATIC SPRING
MAIN VALVE BODY AND STEM GUIDE
VAPOR DISCHARGE VALVE

Fig. 20-12. This fuel pump has a vapor discharge valve. Note how vapor passes through valve. (Lincoln)

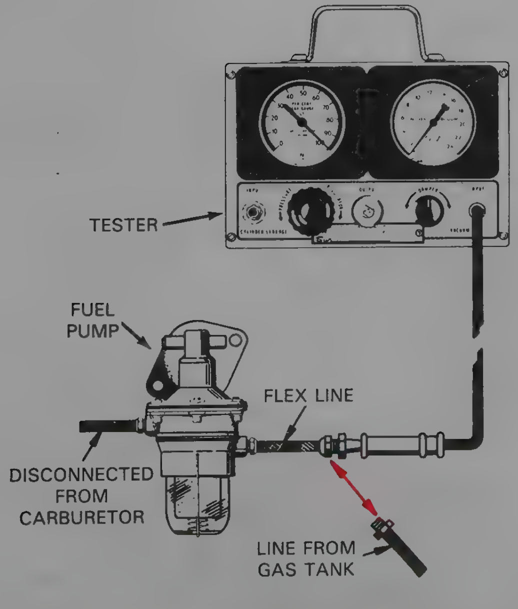

TESTER
FUEL PUMP
FLEX LINE
DISCONNECTED FROM CARBURETOR
LINE FROM GAS TANK

Fig. 20-13. Checking fuel pump inlet vacuum. (Sun Electric)

COMBINATION FUEL AND VACUUM PUMP—VACUUM BOOSTER TEST

If the fuel pump is of the combination fuel-vacuum booster type, the booster pump should also be checked. Note booster portion of the pump shown in Fig. 20-14.

Disconnect the line from the vacuum pump to the intake manifold. Remove the line from windshield wiper or other accessories to booster at the pump. Connect the vacuum gauge at this point.

Operate engine at about 1,000 rpm and note vacuum reading. An average reading should be 8 in. (27 kPa) or more. When the engine is stopped, the reading should hold steady or fall off slowly. Fig. 20-15 illustrates a typical hookup to test a booster pump.

NOTE: A defective booster pump can cause extremely heavy oil consumption. A cracked diaphragm, faulty valve, or poor diaphragm pull rod seal will allow engine vacuum to draw oil and oil vapor from the crankcase

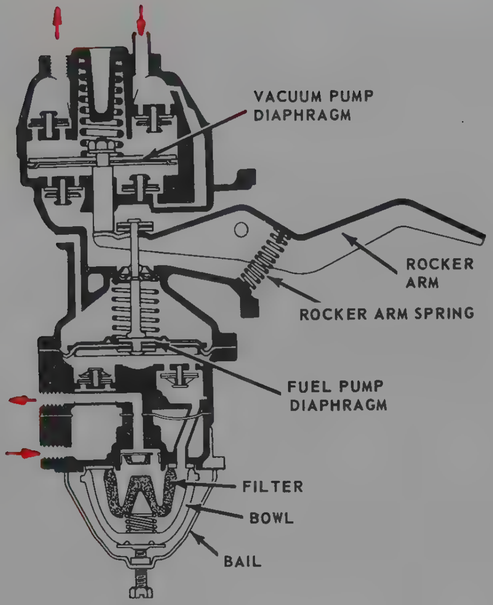

VACUUM PUMP DIAPHRAGM
ROCKER ARM
ROCKER ARM SPRING
FUEL PUMP DIAPHRAGM
FILTER
BOWL
BAIL

Fig. 20-14. Typical combination fuel and vacuum pump. (American Motors)

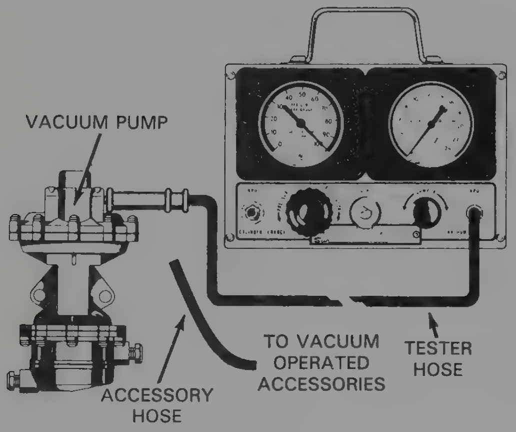

VACUUM PUMP
TO VACUUM OPERATED ACCESSORIES
TESTER HOSE
ACCESSORY HOSE

Fig. 20-15. Setup for checking vacuum booster pump. Vacuum accessory hose is removed and test hose attached. (Sun Electric)

into the intake manifold. In cases of heavy oil burning, always check the vacuum booster, if one is used.

ELECTRIC FUEL PUMPS

Electric fuel pumps come in DIAPHRAGM, BELLOWS, IMPELLER, and ROLLER-VANE types. Accurate pressure and volume tests depend upon a properly charged battery and mechanically sound motor or solenoid. Check wires for good connections. The electric pump (impeller type) shown in Fig. 20-16 is placed inside the gas tank. When stopped, there is no residual line pressure. Do not run dry pumps.

ELECTRIC FUEL PUMP INERTIA SWITCH

Some vehicles use an inertia switch to turn off the electric fuel pump during an accident. In a typical inertia switch, a steel ball is held in place by a magnet. See Fig. 20-17. On impact, the ball breaks away, rolls up a ramp, and strikes a target plate. The target plate opens an electrical switch, which turns the fuel pump off. The electrical switch must be manually reset before restarting the vehicle. A digital volt/ohm meter can be used to test the electric fuel pump inertia switch. If the voltage reading across the electrical contacts exceeds 0.3 volts when the circuit is energized, the switch must be replaced.

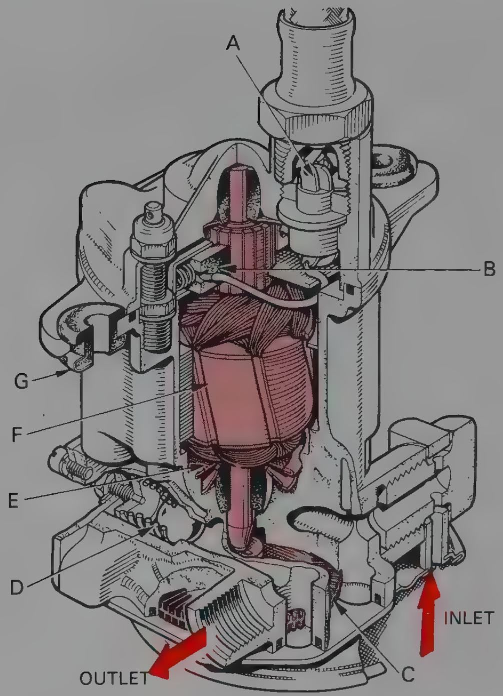

A
B
G
F
E
D
INLET
OUTLET
C

Fig. 20-16. Impeller type electric fuel pump. A-Terminal. B—Brushes. C—Impeller. D—Relief valve. E—Flame trap. F—Armature. G—Anti-static ground washer. (Jaguar)

FUEL PUMP REPAIR

Pump repair kits are of two basic types:

1. A diaphragm kit containing a pump diaphragm,

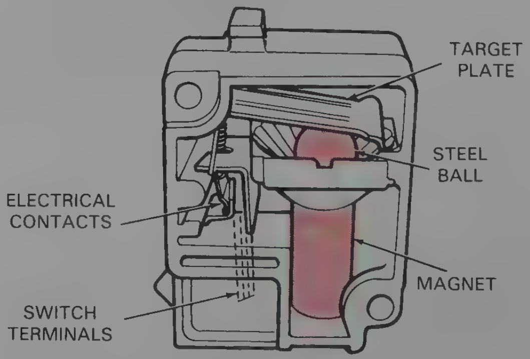

TARGET PLATE
STEEL BALL
ELECTRICAL CONTACTS
MAGNET
SWITCH TERMINALS

Fig. 20-17. Cutaway view of an inertia switch. Caution: If you see or smell fuel, do NOT reset switch until fuel leak is corrected. (Ford)

valves, pulsation diaphragm, diaphragm rod oil seal, and a pump-to-engine gasket.

2. A complete repair kit, in addition to the above, includes a diaphragm spring, rocker arm, rocker arm pin, and spring.

When ordering a pump repair kit, specify what type (diaphragm or complete repair) and give car make, year, and model, and also the pump number. See Fig. 20-18.

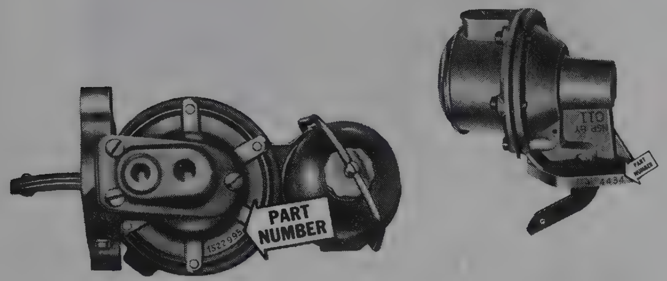

PART NUMBER
PART NUMBER

Fig. 20-18. When ordering either a new pump or a repair kit, be sure to give pump number. (AC)

PUMP REMOVAL

Clean around the pump line connections and mounting flange. Remove line connections, then flange fasteners. Cover line ends and stuff a clean rag into the engine pump rocker arm opening. If a push rod is involved, it should be removed for cleaning and inspection. Brush the outside of the pump with solvent and rinse off.

MARK BEFORE DISASSEMBLY

Scribe a line, as shown in Fig. 20-19, so that the parts may be reassembled in their correct relationship.

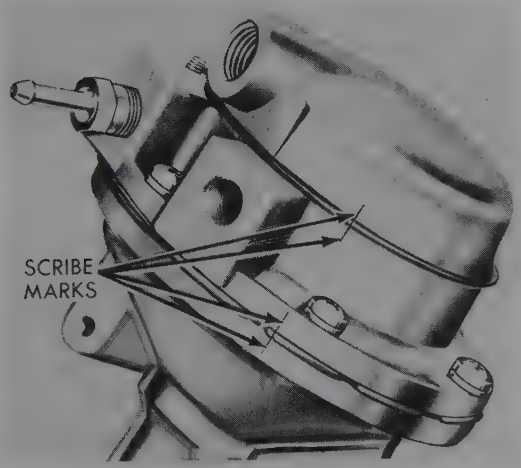

SCRIBE MARKS

Fig. 20-19. Scribe across parting surfaces before disassembly.

PUMP DISASSEMBLY

Disassembly procedures will vary somewhat depending on the pump design—mechanical, electrical, fuel, or combination fuel-vacuum.

The pump shown in Fig. 20-20 and the disassembly instructions are typical.

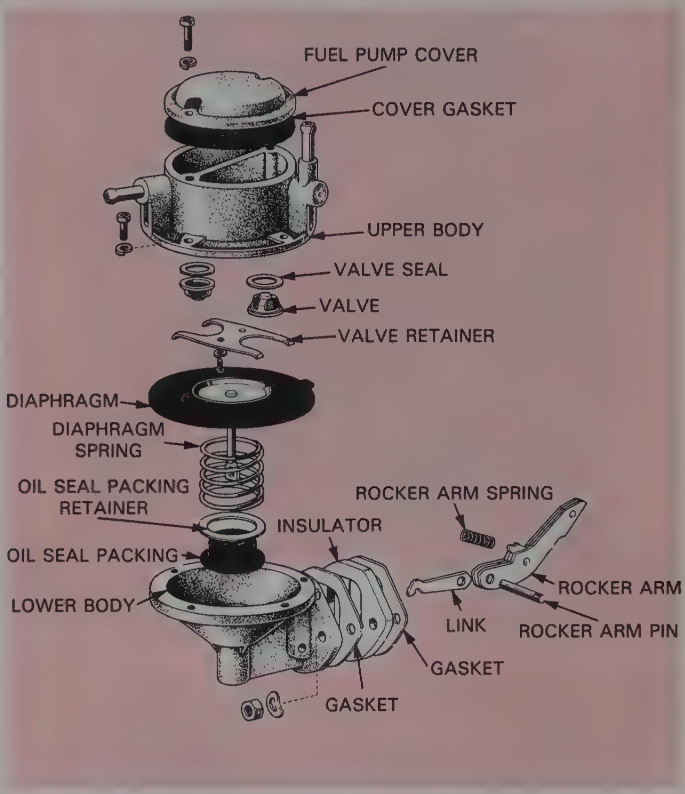

FUEL PUMP COVER
COVER GASKET
UPPER BODY
VALVE SEAL
VALVE
VALVE RETAINER
DIAPHRAGM
DIAPHRAGM SPRING
OIL SEAL PACKING RETAINER
ROCKER ARM SPRING
INSULATOR
OIL SEAL PACKING
ROCKER ARM
LOWER BODY
LINK
ROCKER ARM PIN
GASKET
GASKET

Fig. 20-20. Typical serviceable fuel pump. (Toyota)

Remove the pulsator diaphragm cover (valve body cover). Note the relationship of pulsator to valve body. Discard the pulsator diaphragm. Remove the valve body-to-pump body screws. On combination fuel and vacuum pumps, the strong spring in the vacuum section makes it advisable to remove one screw from each side and replace them with longer ones. Remove the short screws and then let the vacuum housing and body come apart by alternately loosening each of the long screws. See Fig. 20-21.

Remove the stake marks (metal dented or peened) from valve assemblies and pry valves out of body. Note location and position (up or down) of valves so that the new valves may be installed correctly.

Some pumps have valves secured with a retaining bracket and a screw.

Withdraw the rocker arm pin by removing the retaining washer and driving the pin out with a punch. Some pumps have a plug that must be removed. After plug removal, depress the diaphragm and shake out

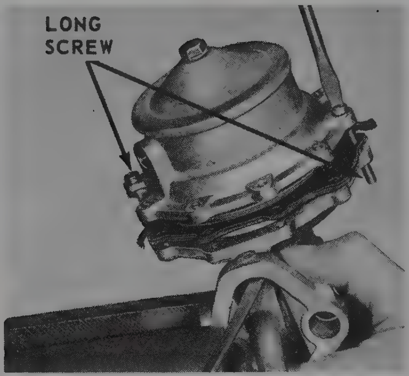


Fig. 20-21. Use of two long screws greatly facilitates assembly and disassembly of vacuum pump section. (AC)

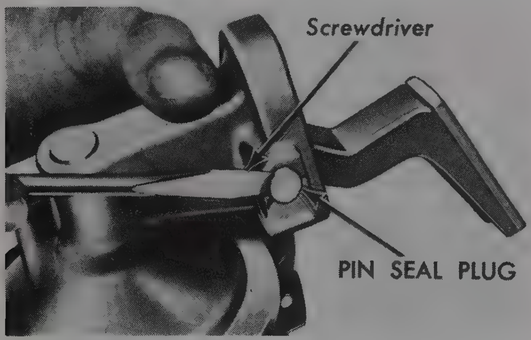


Fig. 20-22. When pin seal plug is removed, rocker arm pin can be shaken out. (Ford)

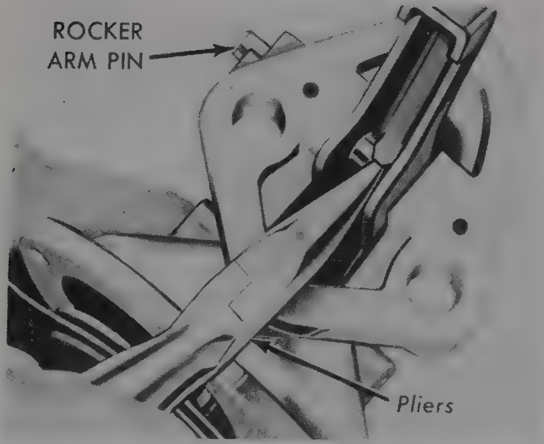


Fig. 20-23. If rocker arm pin does not shake out readily, use needle nose pliers to work pin sideways until it may be grasped for removal. (Mercury)

the rocker arm pin. If it does not fall out, use needle nose pliers to work the pin free from the housing. See Figs. 20-22 and 20-23.

Pull the rocker arm and link assembly from the pump body, unhooking the link from the diaphragm operating rod. Note relative positions of the link and rocker arm assembly.

Remove the diaphragm and rod. Pull the seal and seal retainer. A special puller is handy where the seal is staked in place, as shown in Fig. 20-24.

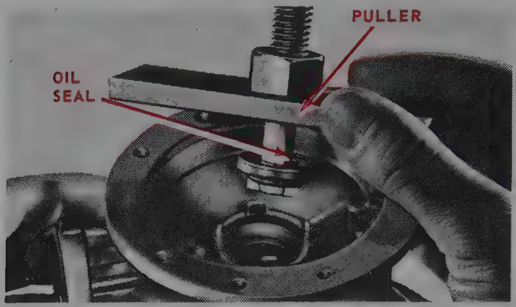


Fig. 20-24. Using a special puller to remove pull rod oil seal. (AC)

CLEAN THOROUGHLY

Place all metal parts of the pump in carburetor cleaner. Soak them the time recommended for the cleaner. Then remove, rinse, and blow dry. Direct a hard stream of air into all parts of the pump. Lay out the parts on a CLEAN surface.

Inspect the rocker arm pin, rocker arm bushing, link, and rocker arm-to-eccentric surface for excessive wear. Inspect the pump body, cover, and other parts for cracks.

Open the repair kit (as described previously) and lay out all parts. Discard the old parts duplicated by those in the kit.

PUMP ASSEMBLY

The parts must be clean. Assemble them in correct relationship to each other. When grasping the pump in a vise, do not tighten it too much as pump parts are easily broken. Never pound or use undue force to assemble. All machined surfaces must be free of nicks and warpage. Replace all worn parts.

VALVE INSTALLATION

Valves are held in position either by staking in place or by using a retainer and screw. Make certain the valves are in the correct holes and are positioned to function properly. One valve must function as an INLET and the other as an OUTLET. Use gaskets with the valves.

Fig. 20-25 shows a valve being seated in its bore. Hammer lightly. Do not damage the valve by using a poorly designed driving tool. Following seating, this valve must be staked to prevent loosening.

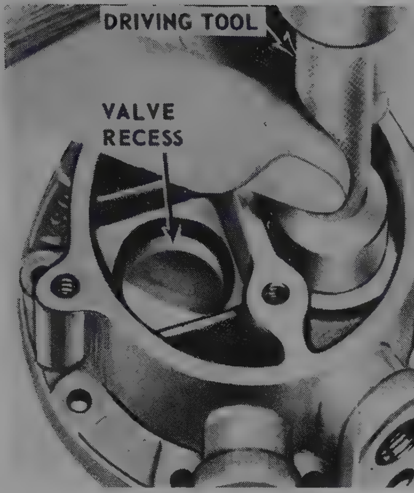


Fig. 20-25. Driving a fuel pump valve into place. (Ford)

PULL ROD OIL SEAL INSTALLATION

Diaphragm pull rod oil seals are of two basic designs. One, usually of a bellows design with a retaining ring, is forced into a recess. It is secured by staking. The other type is a flat washer or modified bellow type, Figs. 20-12 and 20-16, that is held in place by the pressure of a diaphragm spring.

If working with the staked bellows type, use a suitable driver to seat the seal. Stake in at least three spots to prevent loosening. Small end of bellows must face diaphragm. See Fig. 20-26.

If the seal is the "sandwich" washer type held by the diaphragm spring, it will be assembled later. Both types should be thoroughly lubricated with engine oil before assembly.

DIAPHRAGM AND ROCKER ARM INSTALLATION

On some pumps, the rocker arm can be installed first. The diaphragm pull rod is then inserted, tipped, and hooked over the rocker arm link.

Some seal designs allow little or no tipping or side movement of the pull rod. In these cases, it is necessary to insert the pull rod and, while holding it in, the rocker link can be engaged. A modification of this method is to install the rocker arm and hold it in place with an undersize pin, Fig. 20-27. This allows the rocker arm link assembly to be shifted back far enough to permit engaging the pull rod without damage to the seal.

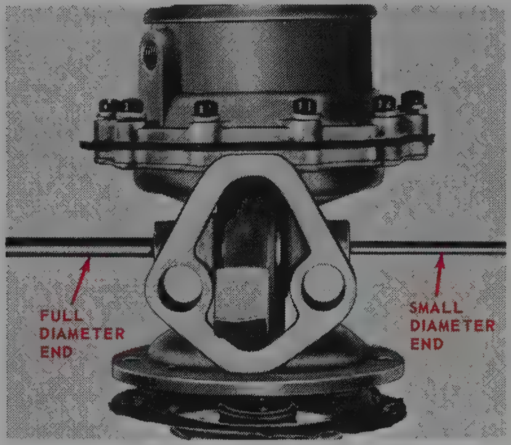


Fig. 20-27. Using small end of a rocker arm installing tool to hold rocker in position. Rocker can then be shifted back far enough to allow engagement of diaphragm pull rod. (AC)

Lubricate the diaphragm pull rod with engine oil or Lubriplate. If a "sandwich" seal is used, assemble and position. Hold the pump in a vise (clean, soft jaws) and pass the pull rod through the seal and into the body. Diaphragm return spring must be in place. The pull rod should be aligned so that the link engagement surface is positioned to engage the link. See Fig. 20-28.

While holding the diaphragm flush with the pump body (tip link end of rod a trifle toward rocker arm), engage the rocker arm and rocker arm link, depending

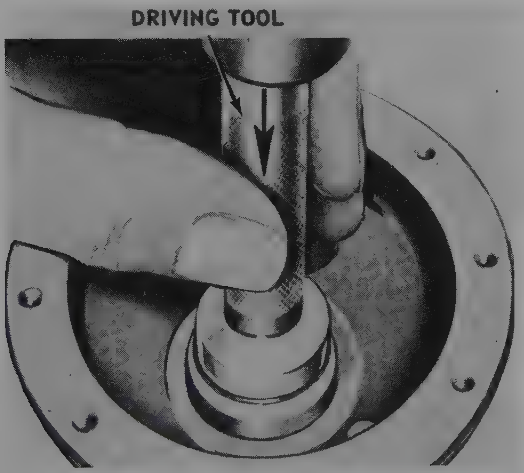


Fig. 20-26. Driving a pull rod oil seal into position.

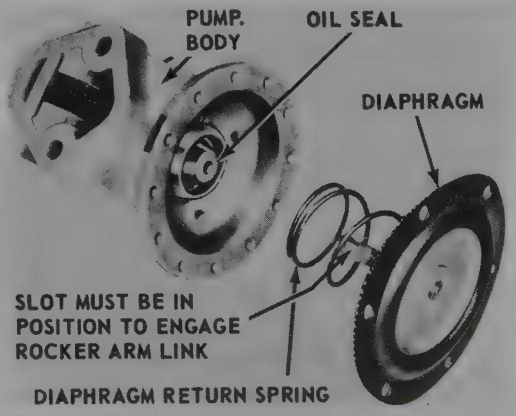


Fig. 20-28. Assembling diaphragm to pump body.

upon design. Slip a pilot pin through the rocker arm. Insert rocker arm spring (on some models spring must be in position before inserting rocker).

The rocker link assembly used in the combination fuel and vacuum pump has a number of pieces. Make sure they are correctly positioned before installing the rocker arm. See Fig. 20-29.

When installing the rocker arm, make sure the rubbing or contact surface is facing in the correct direction.

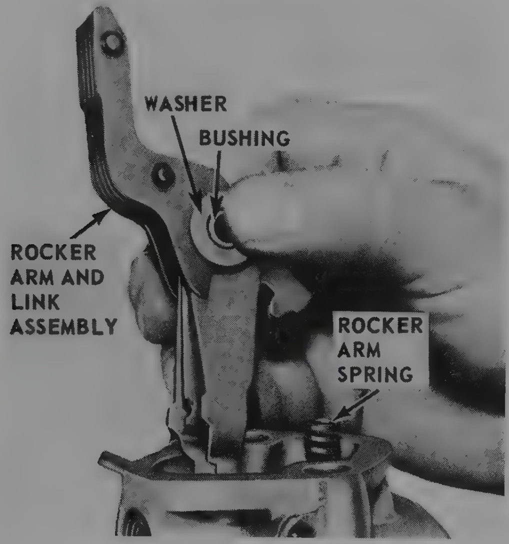

WASHER
BUSHING
ROCKER ARM AND LINK ASSEMBLY
ROCKER ARM SPRING

Fig. 20-29. Rocker arm and link parts must be correctly assembled before installing rocker unit. (G.M.C.)

INSTALL ROCKER ARM PIN

Drive the rocker arm pin into place, as indicated in Fig. 20-30. As it enters, the pilot pin will be forced out.

If a seal plug is used, drive a new one into position to hold pin. Where a retaining washer is used, install washer and peen end of pin. If staking is required, stake at both ends of the pin. The pin must be a snug fit in the body to prevent oil leaks. See Fig. 20-31.

CHECK OIL SEAL POSITION ON DIAPHRAGM PULL ROD

Lift up one side of the diaphragm and check the positioning of the staked bellows oil seal (where used) on the pull rod. It must be fully extended as shown in A, Fig. 20-32. If it is doubled over, B, Fig. 20-32, shove the diaphragm pull rod in with a slight twisting motion. Release and check. Repeat until seal has snapped into the correct position. If the seal refuses to snap up into position, apply a vacuum to the diaphragm vent hole AFTER the diaphragm is secured between pump body and cover.

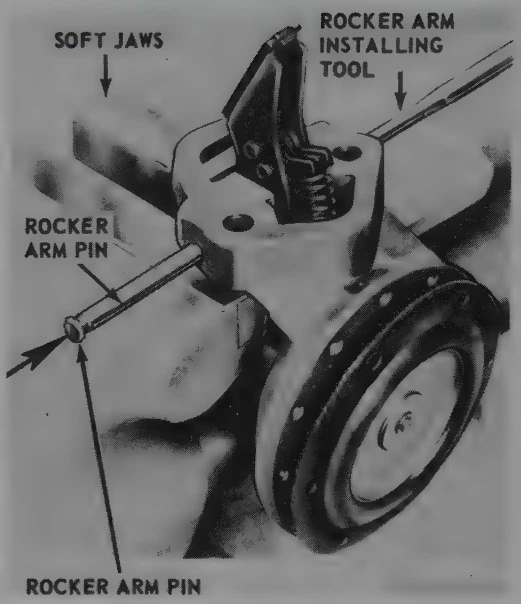

SOFT JAWS
ROCKER ARM INSTALLING TOOL
ROCKER ARM PIN
ROCKER ARM PIN

Fig. 20-30. When rocker arm pin is driven into place, it will force installing tool out. (Ford)

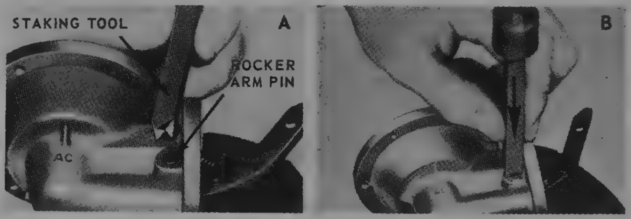

STAKING TOOL
A
ROCKER ARM PIN
AC
B

Fig. 20-31. Left. Rocker arm pin and staking tool. Right. Staking rocker arm pin. (AC)

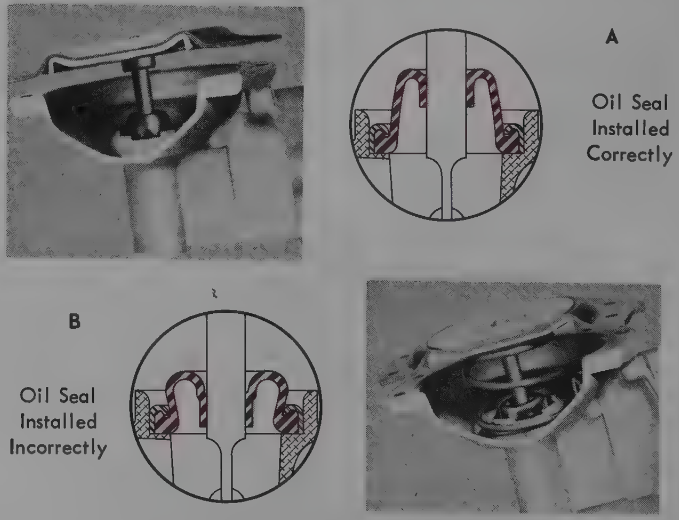

A
Oil Seal Installed Correctly
B
Oil Seal Installed Incorrectly

Fig. 20-32. Pull rod oil seal must be positioned correctly on rod.

HOLD THE DIAPHRAGM FLUSH WITH BODY

Move the rocker arm far enough to pull the diaphragm down until it is level with the body parting

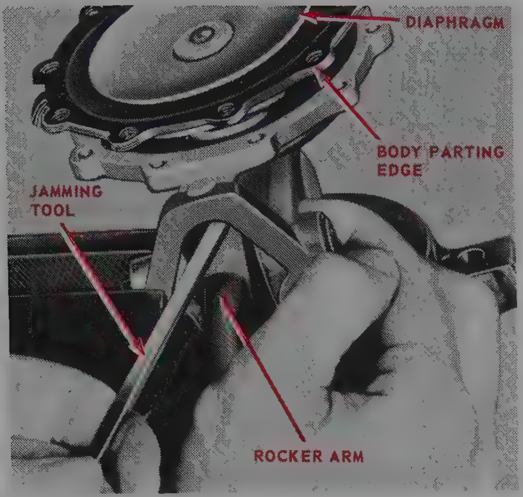


Fig. 20-33. Jam rocker arm to hold diaphragm flush with body parting edge.

edge. Jam the rocker to hold it in this position, Fig. 20-33.

ATTACH VALVE BODY

Place valve body into position over diaphragm. Align scribe marks. Start all fasteners. Make certain they pass through the diaphragm without tearing. Run screws in until they just start to tighten against the lock washers. At this point, if the diaphragm is the FLAT type, move the rocker arm to flex the diaphragm down as far as possible. While holding in this position, securely tighten one screw on each side of the diaphragm. Release pressure on rocker arm and tighten the remaining screws. If the diaphragm is of the FORMED type, Fig. 20-16, do not flex downward before tightening.

NEW PULSATOR DIAPHRAGM

Install the new pulsator diaphragm. If the diaphragm has an opening, as shown in Fig. 20-34, make sure it is positioned over the inlet chamber.

Place pulsator cover over pulsator diaphragm and tighten screws.

If a filter bowl is used, install a new filter and tighten the bowl bail nut. Where a filter screen is used, it must be clean. Use a new bowl gasket. Recheck all fasteners. Lubricate rocker arm assembly.

PUMP INSTALLATION

Use a new mounting gasket and coat with gasket cement.

Make certain the rocker arm rubbing pad (contact surface) bears against the eccentric or the push rod where used. Mounting the rocker rubbing pad to one side of the eccentric or off the push rod can cause pump breakage and, in some instances, engine damage. Fig. 20-35 shows three possible rocker arm pad-to-eccentric contact arrangements.

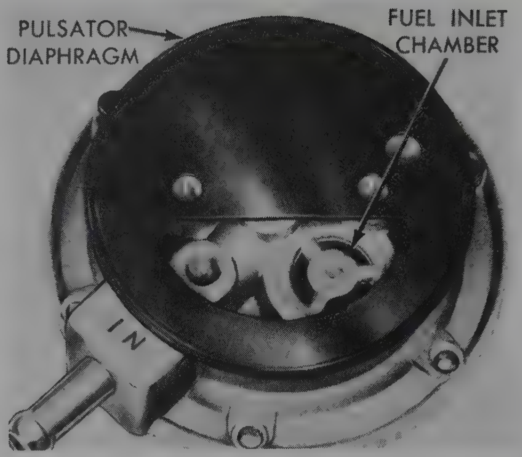


Fig. 20-34. Pulsator opening must be over inlet chamber. (Ford)

Study the shape of the rocker arm and note the positioning of the pad. Check location of cam or push rod and install pump to make correct contact.

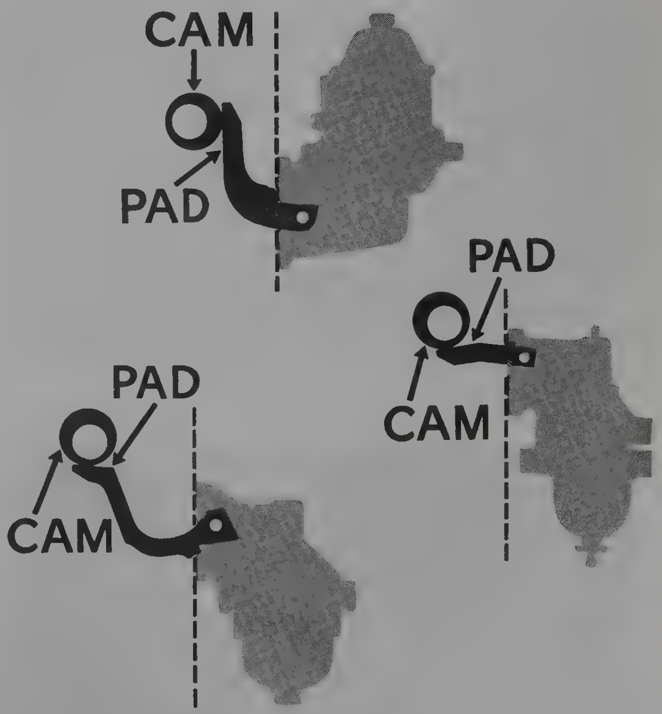


Fig. 20-35. Three different rocker arm contact pad-to-eccentric (cam) arrangements. (AC)

Shove pump inward until the mounting flange is against the mounting pad. Install fasteners and torque to specifications. See Fig. 20-36. Never force the pump home by using the fasteners to pull it in.

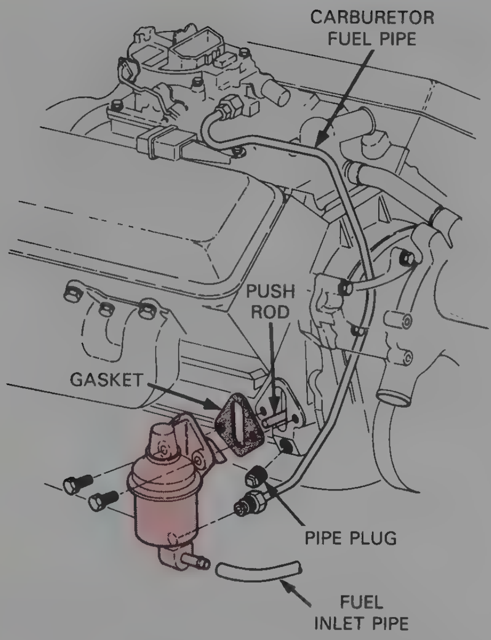


Fig. 20-36. When installing a fuel pump, make certain rocker arm contacts cam or as in this case,the push rod, correctly. Do not use fasteners to force pump into place. (AC)

ATTACH FUEL LINES

Attach the fuel lines or hose, as the case may be. Flex hose must be in good condition. Fittings must align to prevent cross threading. Tighten pump fittings and then attach lines. Hold pump fitting with one wrench while tightening flare nut with the other. See Fig. 20-37.

When using tube fittings of the "Push Connect" type, make certain tube is clean. Check fitting inside for cleanliness. Align fitting and tube and shove fitting on tube. Be certain to replace retaining clip. A Push Connect fitting is pictured in Fig. 20-38.

Start engine and check for leaks. Test pump pressure and volume.

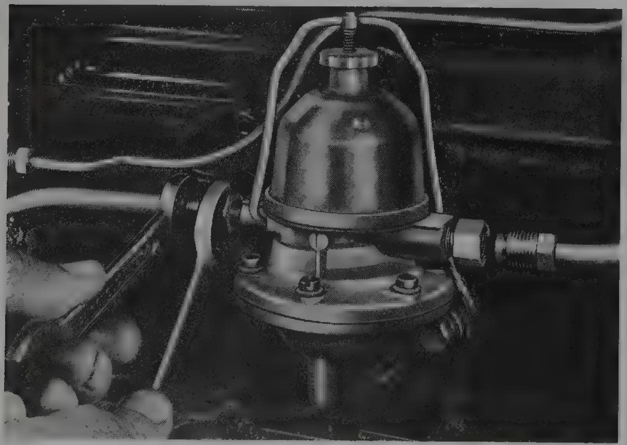


Fig. 20-37. Tighten fittings securely. Do not cross thread. Note how mechanic is holding pump fitting while tightening flare nut. (AC)

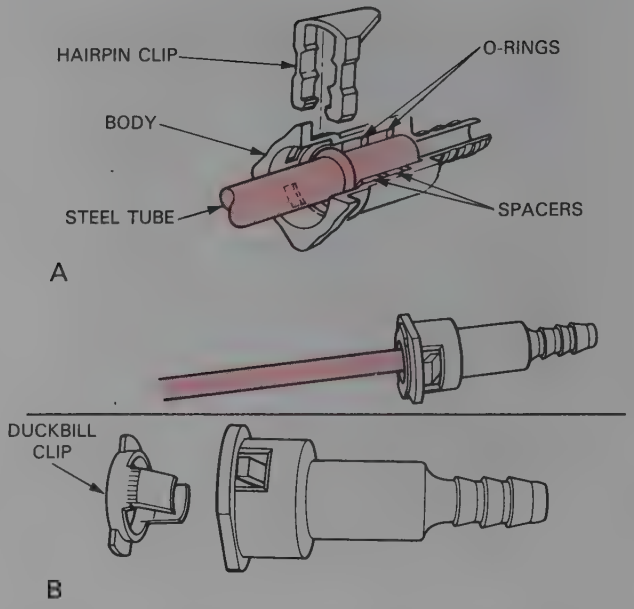


Fig. 20-38. Two retainer clip styles for a Push Connect fuel line fitting. A—"Hairpin" clip. B—"Duckbill" clip. After installation, pull on fitting to make certain it has snapped into place securely. (Ford)

FUEL FILTER SERVICE

Current trend is toward the use of various disposable filters. Some utilize a paper element that may be changed. Others require disposal of the entire unit, Figs. 20-39 and 20-40.

The traditional bowl-type filter is pictured in Fig. 20-41. The paper element shown should be discarded when clogged. Other element types, such as the screen, porous bronze, cuno, and ceramic, can be cleaned and blown dry.

Some carburetor designs incorporate a filter in the fuel inlet, as shown in Fig. 20-42.

Diesel fuel systems should protect against the entry of water into the injector pump where it can cause serious damage. Many systems utilize a filter that not only removes rust and dirt particles, but that acts as a water trap as well. One such filter is pictured in Fig. 20-43. This particular filter incorporates a water sensor to actuate a dash light when water is present. The filter also has a provision for draining off any water, Fig. 20-43.

Filters play an important part in maintaining a properly running engine. Clean or change at recommended intervals or as needed. When apparent fuel pump troubles occur, check filters to make certain they are clean. Some require presoaking to remove filter particles, which can clog injectors. Always check for leaks after servicing filters.

VAPOR LOCK

Vapor lock is a condition in which the fuel in the lines or pump becomes heated to the extent that it

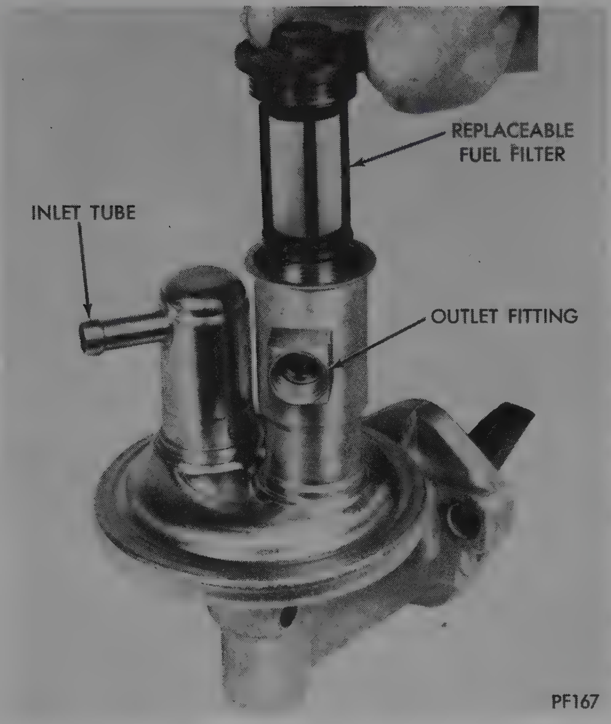

REPLACEABLE FUEL FILTER
INLET TUBE
OUTLET FITTING
PF167

Fig. 20-39. This fuel pump uses a replaceable fuel filter. (Plymouth)

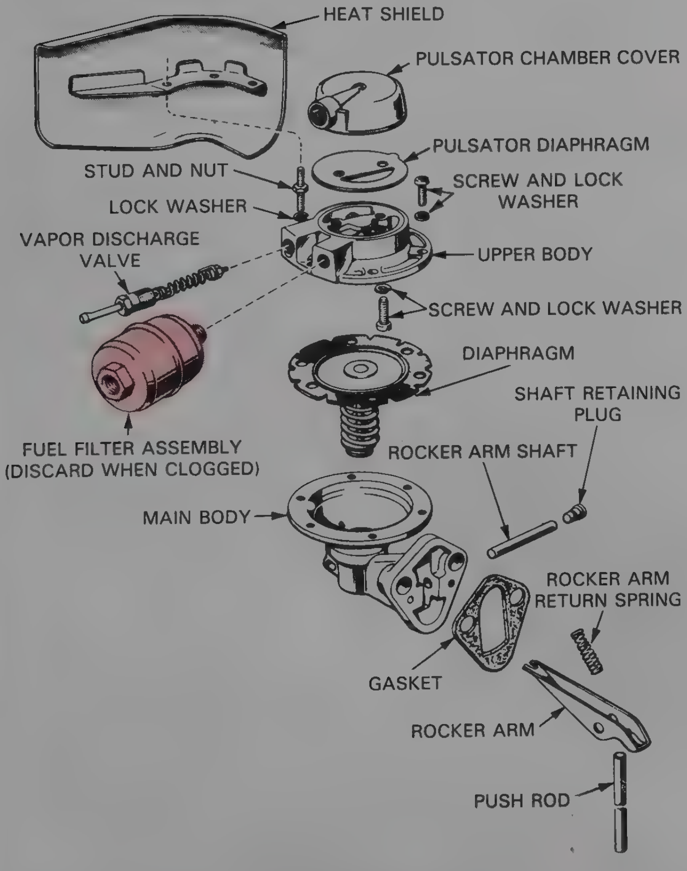

HEAT SHIELD
PULSATOR CHAMBER COVER
PULSATOR DIAPHRAGM
STUD AND NUT
SCREW AND LOCK WASHER
LOCK WASHER
VAPOR DISCHARGE VALVE
UPPER BODY
SCREW AND LOCK WASHER
DIAPHRAGM
SHAFT RETAINING PLUG
FUEL FILTER ASSEMBLY (DISCARD WHEN CLOGGED)
ROCKER ARM SHAFT
MAIN BODY
ROCKER ARM RETURN SPRING
GASKET
ROCKER ARM
PUSH ROD

Fig. 20-40. This entire filter assembly must be discarded when clogged. (Lincoln)

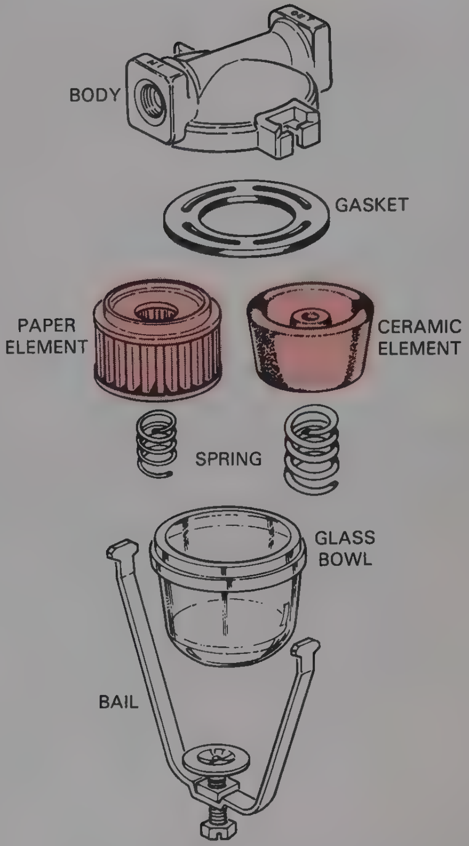

BODY
GASKET
PAPER ELEMENT
CERAMIC ELEMENT
SPRING
GLASS BOWL
BAIL

Fig. 20-41. Bowl type filter showing two types of filter elements. Ceramic filter can be cleaned. Replace a paper element filter. (Hastings)

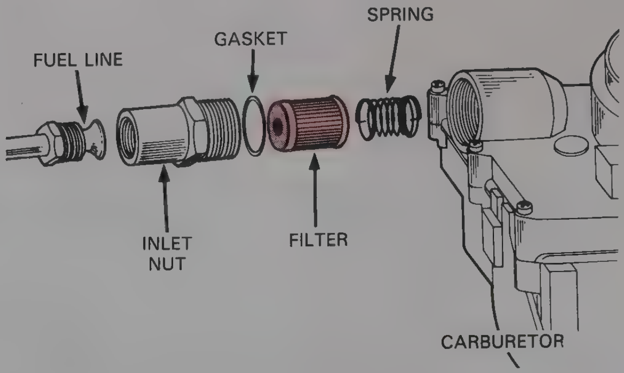

SPRING
GASKET
FUEL LINE
INLET NUT
FILTER
CARBURETOR

Fig. 20-42. One type of carburetor inlet fuel filter. (AC)

begins to vaporize. The vaporization causes the formation of tiny air bubbles. If enough bubbles are formed, fuel flow to the carburetor can be reduced, and in severe cases, stopped.

Using highly volatile gasoline during hot weather, running fuel lines too close to the exhaust manifold, excessive looping and bending of the fuel line, failure to reinstall a heat shield can all cause vapor lock. See Figs. 20-40 and 20-44.

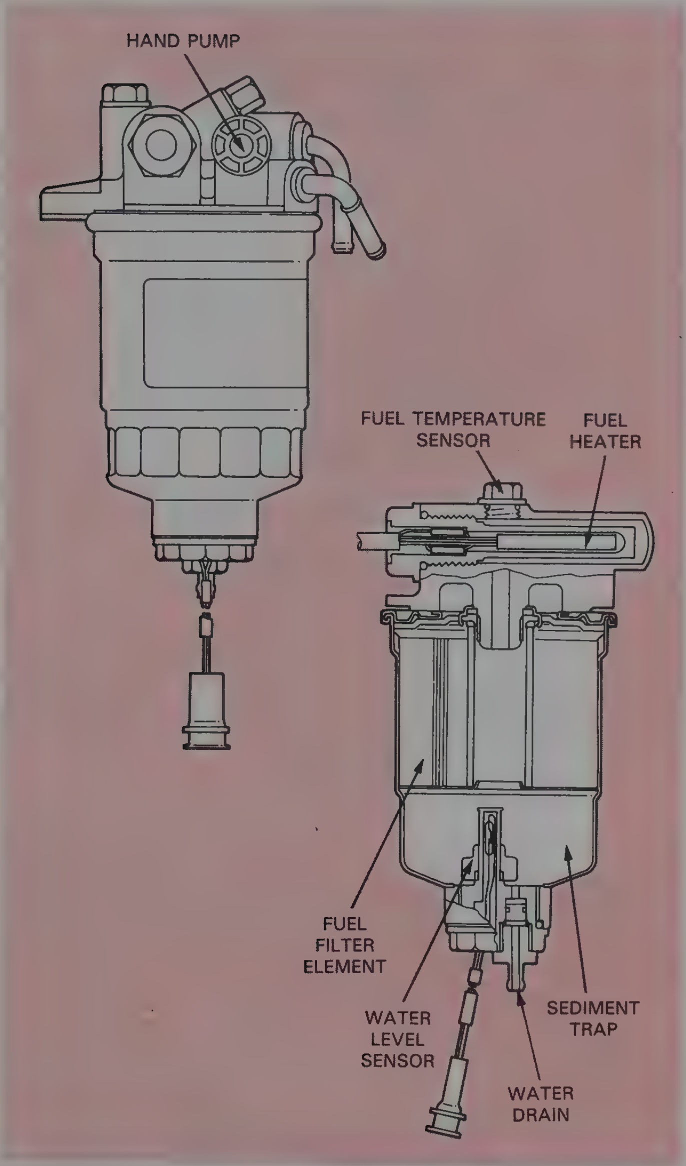


Fig. 20-43. Diesel fuel system filter. This setup uses a water sensor to warn of water in filter. A water separator and drain are also included. (Chrysler)

When vapor lock occurs, it can be temporarily cured by stopping the engine and placing cold wet rags on the lines and pump. As soon as the fuel cools, the vapor condenses and the car should start.

To correct the situation, determine the reason for the vapor lock and make necessary repairs.

SUMMARY

Fuel tanks are constructed of treated steel or plastic.

Remove fuel from tank prior to tank removal. Use a special siphoning device to remove fuel from tank. Store fuel in safety cans.

Steel tanks can be repaired by soldering or brazing. Use correct technique and be careful to prevent an explosion. REMEMBER – FUEL TANKS CAN EXPLODE WITH MASSIVE FORCE!

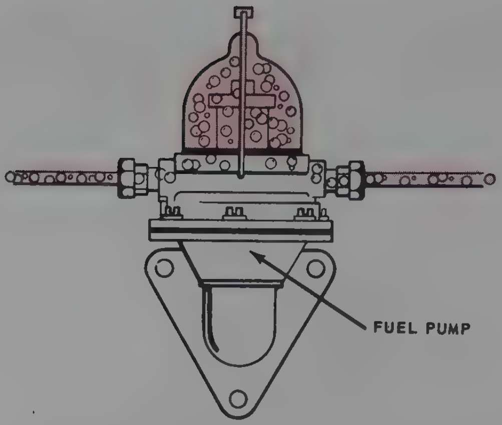


Fig. 20-44. Overheated fuel vaporizes and forms tiny bubbles that cause vapor lock. Fuel flow will be slowed down, and in severe cases, stopped. (Automotive Electric Assoc.)

Fuel lines can be cleaned by forcing air through them. Disconnect lines first. Do not admit air pressure to fuel tank.

Fuel pumps are either vacuum or electric operated. Some pumps are located in the tank. Pumps may be of serviceable or nonserviceable design.

Test fuel pumps for flow volume, pressure, and inlet vacuum. Use proper tools. Observe care to prevent fire from spraying or leaking fuel.

When rebuilding a serviceable pump, use care to select the correct repair kit. Install all parts in their proper location and position.

Attach vacuum operated pumps carefully so that rocker arm contacts cam or rod properly.

When a replacement is required, use proper size and type tubing or hose. Route away from hot areas or use heat baffles. Protect from vibration.

Attach fuel lines securely and avoid cross threading. Use a flare nut wrench. Support fitting while tightening flare nut.

Keep fuel filters clean. Service filter or replace if of disposable type.

Vapor lock can slow or completely stop delivery of fuel to the carburetor. Use proper fuel and protect lines from heat to minimize chances of vapor lock.

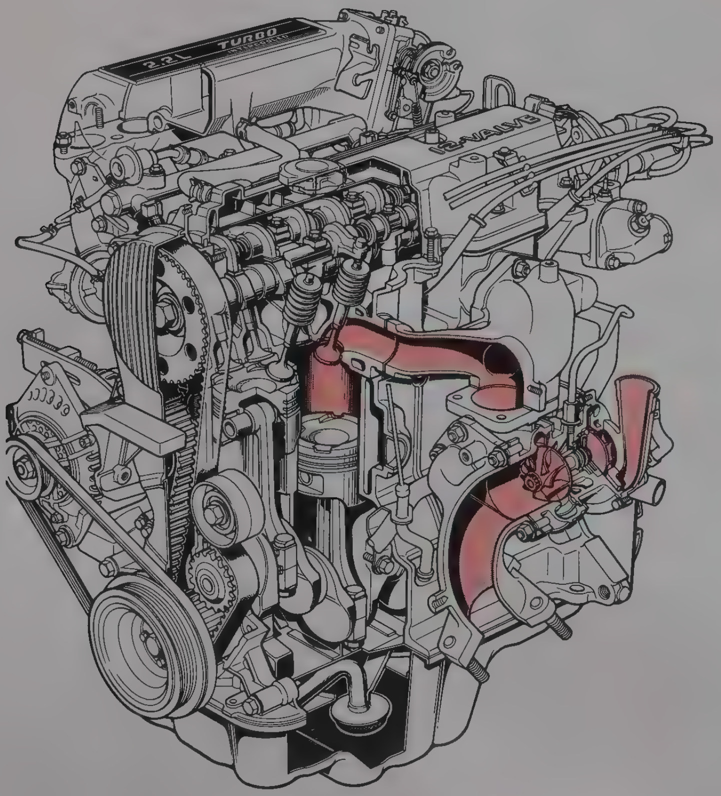
KNOW THESE TERMS

Siphon, Toxic, Fuel pump, Fuel pump pressure, Fuel pump volume, Fuel pump vacuum, Combination fuel and vacuum pump, Pump diaphragm, Rocker arm, Vapor lock, Water sensor.

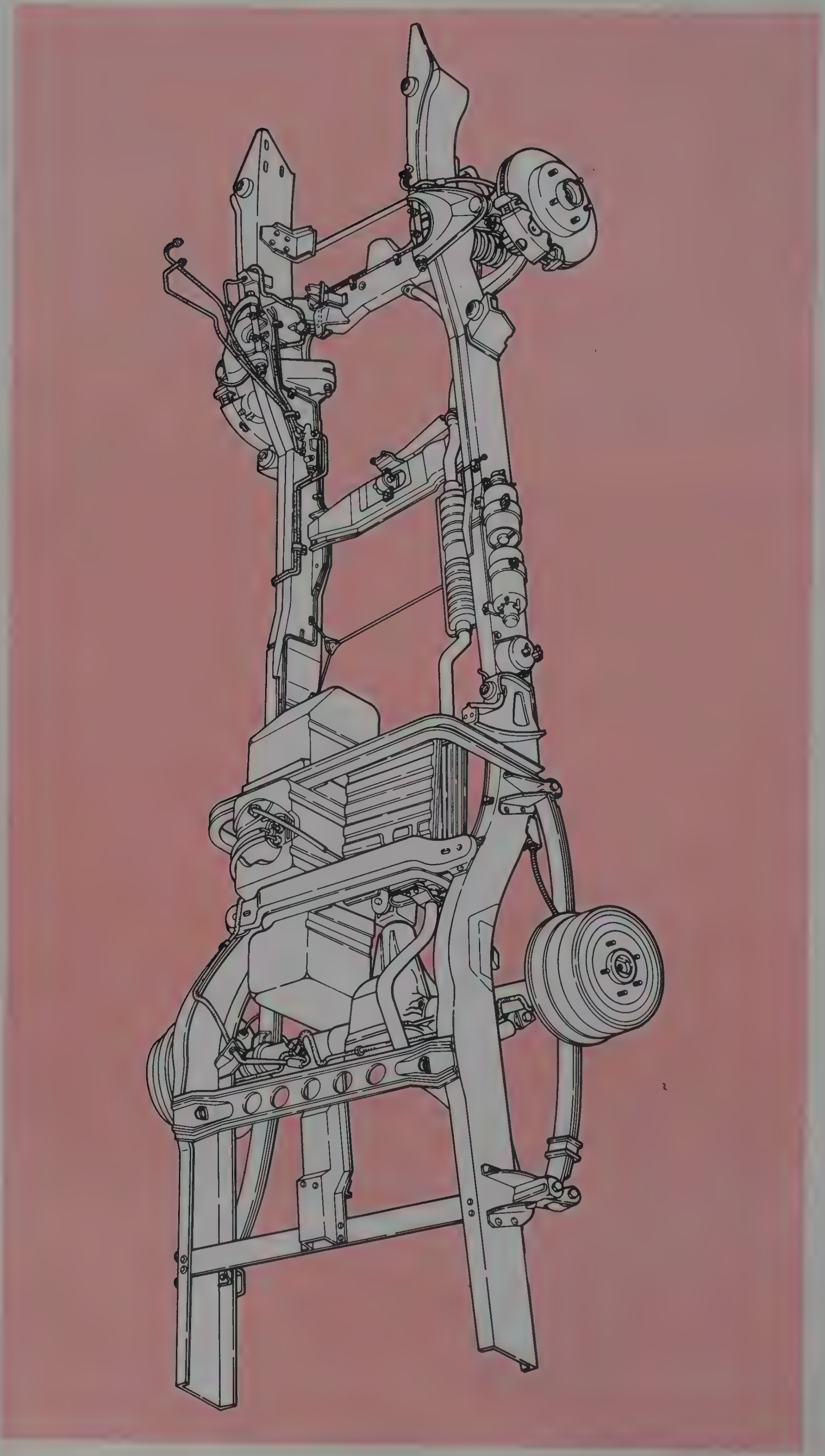
QUIZ—Chapter 20

1. When a fuel tank has no drain, how is the gasoline best removed?

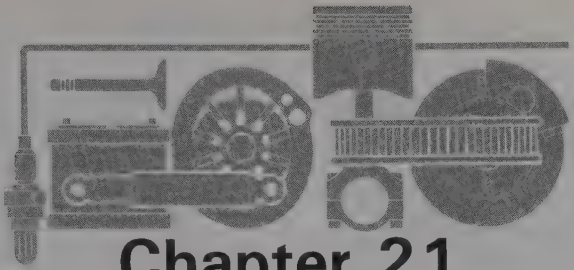
2. If the inside walls of a fuel tank are rusted, the tank should be:
   a. Discarded.
   b. Soldered.
   c. Steam cleaned.
   d. Blown out with air.
3. Brazing or soldering a fuel tank must be considered:
   a. More or less hazardous.
   b. Quite hazardous.
   c. Extremely dangerous.
4. Large tank dents can often be removed by filling the tank with ______________ and applying ______________ ______________.
5. When cleaning fuel line, blow from the ______ __________ end towards the ________ ________.
6. Fuel pumps should always be tested for ________ and __________.
7. Before condemning a pump for failing the two tests in Question six, what other test should be performed?
8. On fuel pumps with a vapor return valve, what step must be taken before testing?
9. A defective combination fuel and vacuum pump (vacuum part defective) can cause heavy ________ __________.
10. All fuel pumps may be rebuilt. True or False?
11. Before disassembly, the fuel pump halves should be ___________ to insure correct ___________.
12. Before tightening pump cover screws, the diaphragm, if of flat type, should be compressed __________ and held in position while fasteners are tightened.
13. When installing the fuel pump, be sure that the ___________ ___________ contact surface bears against the cam or eccentric.
14. Do not use fasteners as a means of forcing the fuel pump into place. True or False?
15. When fuel pump trouble is suspected, always check the fuel _________ and the tank _________ before condemning the pump.
16. Explain what causes vapor lock.
17. Diesel fuel systems often employ a special sensor to alert the driver that there is ___________ in the fuel system.
18. Carbon tetrachloride fumes can be deadly. Never breathe them! True or False?
19. Name two things that can cause an expanded fuel tank. Car vapor [illegible]
20. When removing fuel supply lines from fuel injected cars, relieve the:
   a. Tank pressure.
   [✓ b.] Residual line pressure.
   c. Fittings.
   d. Radiator pressure.
21. "Push Connect" type fittings should always be tightened with a low reading torque wrench. [✓ True] or False?



Cutaway view of 2.2-liter, OHC, 12-valve, EFI engine. (Ford)



Frame and frame parts used on a two-wheel drive vehicle. Note fuel tank and connecting lines. Tank has been located inboard of the frame for safety. (Dodge)



Chapter 21

FUEL SYSTEM SERVICE — CARBURETORS

After studying this chapter, you will be able to:

☐ Adjust carburetor idle speed and idle mixture.
☐ Adjust a manual and automatic choke.
☐ Adjust a fuel bowl vent.
☐ Set float level and float drop.
☐ Adjust an accelerator pump.
☐ Disassemble, clean, inspect, and reassemble a carburetor.
☐ Adjust throttle linkage.
☐ Service a manifold heat control valve.
☐ Detect intake manifold air leakage.

WARNING: Carburetor testing, inspecting, and repair involves the possibility of fire or explosion from spilled gasoline. Be careful!

PRE-SERVICE CHECKS

Before performing carburetor diagnosis and/or service, make sure that all related systems are functioning properly. Quite often, what appears to be a carburetor problem turns out to be caused by something else.

Check for possible vacuum leaks around the intake manifold, carburetor mounting gasket, and vacuum hose connections. Inspect all related emission control systems such as exhaust gas recirculation (EGR), positive crankcase ventilation (PCV), computer sensors, and electrical connections. Spark plugs must be clean, properly gapped, and sound. Check ignition timing and ignition secondary wiring. Engine compression should be up to specifications in all cylinders. Fuel must be fresh and of proper octane rating. Fuel delivery system must be functioning properly. Air cleaner must be clean. Check action of intake air heat control devices.

These checks, along with any others related to a specific car, will pay off in time saved. They will often prevent expensive repairs that were not needed and that would fail to correct the problem.

CARBURETOR ADJUSTMENTS

A number of adjustments can be made with the carburetor on the engine. Others require removal and partial or complete disassembly. All affect emissions.

Since there are a number of different makes and countless models of carburetors, no attempt will be made to give information on specific makes and models. Typical adjustments will be discussed. It is imperative that the mechanic use a manual COVERING THE CARBURETOR AT HAND FOR EXACT SPECIFICATIONS.

BE CERTAIN THE CARBURETOR IS AT FAULT

Successful carburetor system performance depends upon a mechanically sound engine, an ample supply of clean fuel, and a properly operating ignition system. Unless the trouble is definitely KNOWN to be in the carburetor, always check these other areas before starting extensive repairs, adjustments, and replacement.

FAST IDLE (COLD IDLE) SPEED ADJUSTMENT

Bring engine to normal operating temperature. Connect tachometer. Shut off engine. Open throttle and adjust fast idle cam so that the fast idle adjusting screw contacts the recommended step or index mark.

Some specifications call for the automatic transmission to be in drive. If this is the case and if the car is equipped with a vacuum emergency brake release, disconnect and attach a vacuum gauge to the vacuum line at the brake release diaphragm or vacuum cylinder. Failure to do this can cause the brake to release, thus allowing the car to lunge forward. It is advisable also to block wheels.

Emergency brake release vacuum line should always be disconnected at the diaphragm to prevent any calibrated leakage in other parts of the vacuum system as well as to permit other vacuum operated units to function.

Turn fast idle adjusting screw in or out to bring rpm to specifications. Specifications average about 750 rpm when screw is resting in the first or lowest step on the cam. See Fig. 21-1.

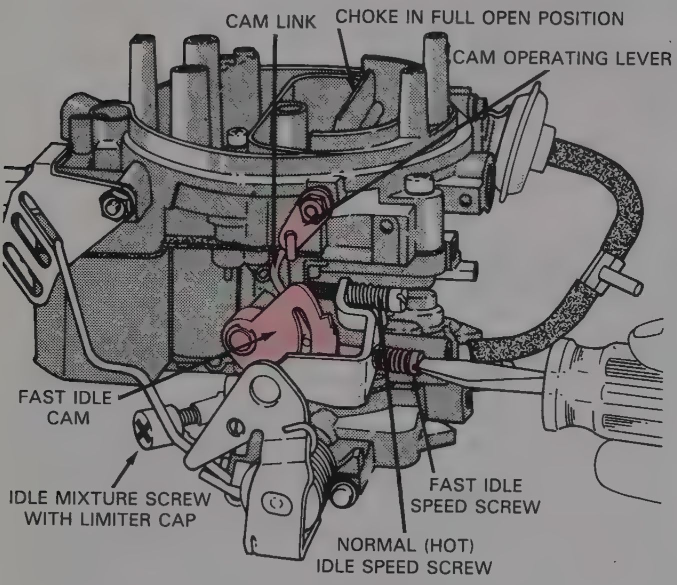

CAM LINK
CHOKE IN FULL OPEN POSITION
CAM OPERATING LEVER
FAST IDLE CAM
IDLE MIXTURE SCREW WITH LIMITER CAP
FAST IDLE SPEED SCREW
NORMAL (HOT) IDLE SPEED SCREW

Fig. 21-1. Fast idle adjusting screw, fast idle cam, and cam operating lever and link. (Chrysler)

ADJUSTING FAST IDLE CAM LINKAGE

Because the fast idle cam position is determined by the degree of choke valve opening, it is important that the relationship be accurate.

Hold the throttle open (engine stopped) and close the choke valve. Some carburetors require that the choke be open a measured distance. Allow the throttle lever to return to the idle position. Note where the fast idle screw contacts the fast idle cam. Specifications call for contact to be on a certain step, or in line with an index mark.

If the contact is off, align the index mark with the fast idle screw and bend the control rod as needed to produce the specified choke valve closure, Fig. 21-2.

If adjustment was necessary, the fast idle rpm setting should be reset.

SLOW IDLE (HOT IDLE) SPEED ADJUSTMENT

Bring engine to normal operating temperature. Check specifications to determine if the automatic transmission (where used) should be in drive or neutral. If it is to be in drive, set the hand brake and block the wheels. If a vacuum emergency brake release is used, disconnect vacuum line at diaphragm and insert a vacuum gauge. Attach tachometer.

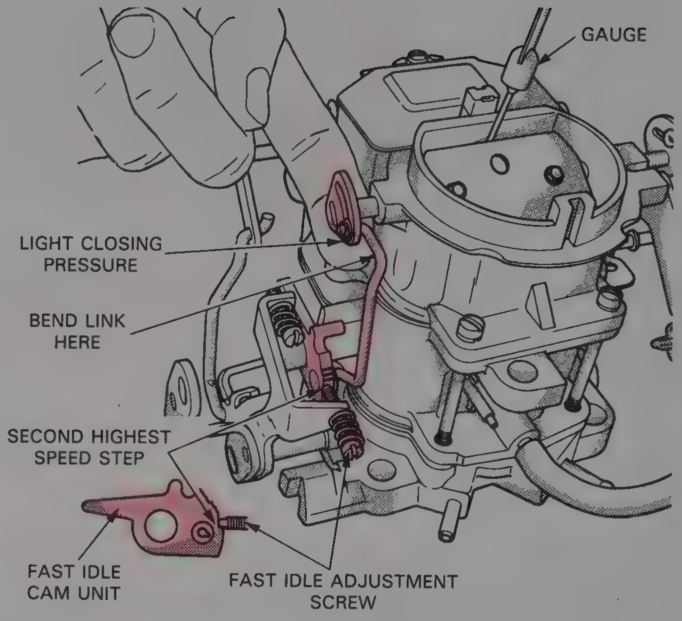

GAUGE
LIGHT CLOSING PRESSURE
BEND LINK HERE
SECOND HIGHEST SPEED STEP
FAST IDLE CAM UNIT
FAST IDLE ADJUSTMENT SCREW

Fig. 21-2. Checking fast idle cam adjustment. Note how fast idle adjustment screw contacts the fast idle cam. (Chrysler)

Check to see if an air conditioning system (where used) should be turned on (when on, idle speed is stepped up automatically). Some specifications require that the headlights be on to load the alternator.

Remove air cleaner. Check choke to make sure it is fully open. Throttle (both primary and secondary) valves must be fully closed (on slow idle).

If a hot idle compensator is used, it must be held closed. See Fig. 21-3. To prevent permanent damage

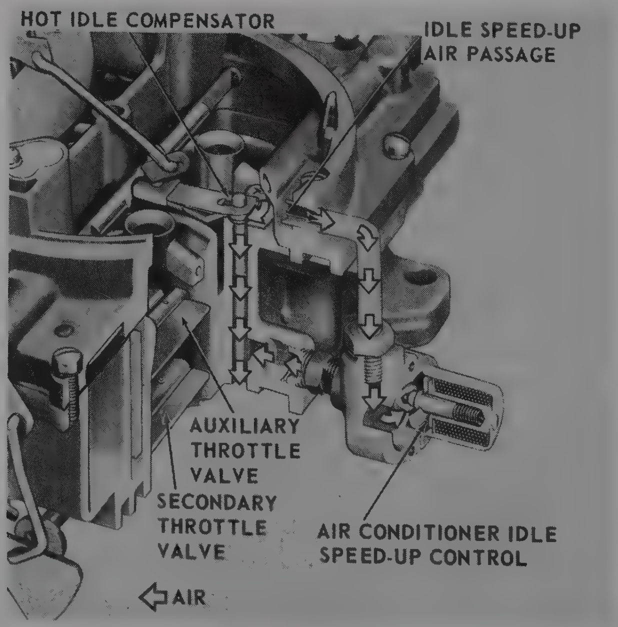

HOT IDLE COMPENSATOR
IDLE SPEED-UP AIR PASSAGE
AUXILIARY THROTTLE VALVE
SECONDARY THROTTLE VALVE
AIR CONDITIONER IDLE SPEED-UP CONTROL
AIR

Fig. 21-3. One type of hot idle compensator valve. (Lincoln)

to the compensator valve, press on the valve end and not on the bimetallic strip. Adjust the idle speed screw to produce the specified rpm.

Some carburetors use an idle air adjusting screw that adjusts idle speed by varying the amount of air admitted to the idle mixture. When setting the idle speed with an idle air adjusting screw, use a minimum amount of air. Turning the screw out admits more air and speeds up the engine. Fig. 21-4 illustrates a typical idle air adjusting screw.

IMPORTANT NOTE: Engine hot idle speed adjustment must ALWAYS BE ACCOMPANIED BY IDLE MIXTURE SCREW ADJUSTMENTS. THIS IS ESPECIALLY IMPORTANT WHERE AN IDLE AIR ADJUSTING SCREW IS USED. INCREASING IDLE RPM LEANS OUT THE IDLE MIXTURE AND DECREASING ENRICHENS IT.

SINGLE SCREW ADJUSTMENT FOR BOTH SLOW AND FAST IDLE

In some applications, a single idle speed adjustment screw is used. If this is the case, adjust for slow (hot) idle with the screw contacting the lowest part of the fast idle cam. The fast idle speed will be automatically adjusted as the choke pulls the cam upward. See Fig. 21-5.

IDLE FUEL MIXTURE—PROPANE ENRICHMENT

Idle mixture adjustments on some carburetors require the use of propane. The propane enters the carburetor through a tube attached to the air cleaner or intake manifold fitting. Propane creates a rich fuel mixture, which is necessary when performing idle mixture adjustments. Admitting propane can be dangerous! Follow all service manual procedures carefully. Tampering with carburetor settings is a violation of Federal Law.

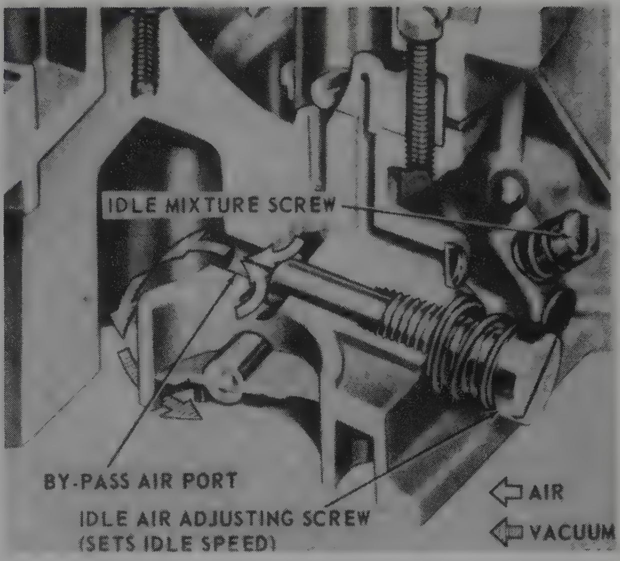


Fig. 21-4. Idle air adjusting screw used on some carburetors to set idle speed.

ADJUSTING IDLE MIXTURE — SINGLE BARREL CARBURETOR

A vacuum gauge and tachometer must be in place. Turn the idle mixture screw in (clockwise) until the engine begins to miss (lean mixture). Note the position of the screw slot. Back the idle mixture screw out (count number of turns) until the engine begins to "roll" (rich mixture). Turn screw back in so as to be positioned halfway between the "missing" and the "roll" spots. From this point, carefully turn the idle mixture screw in or out to produce the highest rpm and vacuum reading.

If the idle speed has changed following the mixture adjustment, reset with the idle speed screw. Repeat the process of adjusting the mixture and setting the idle speed until the vacuum gauge shows the highest reading when the idle speed is as specified.

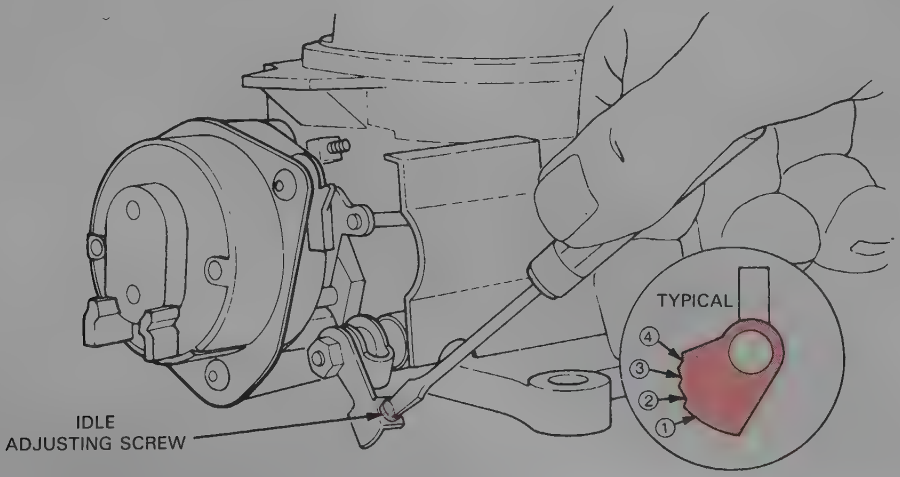


Fig. 21-5. Idle rpm adjustment. Note the four different cam steps. Each step will change the speed setting. (Ford)

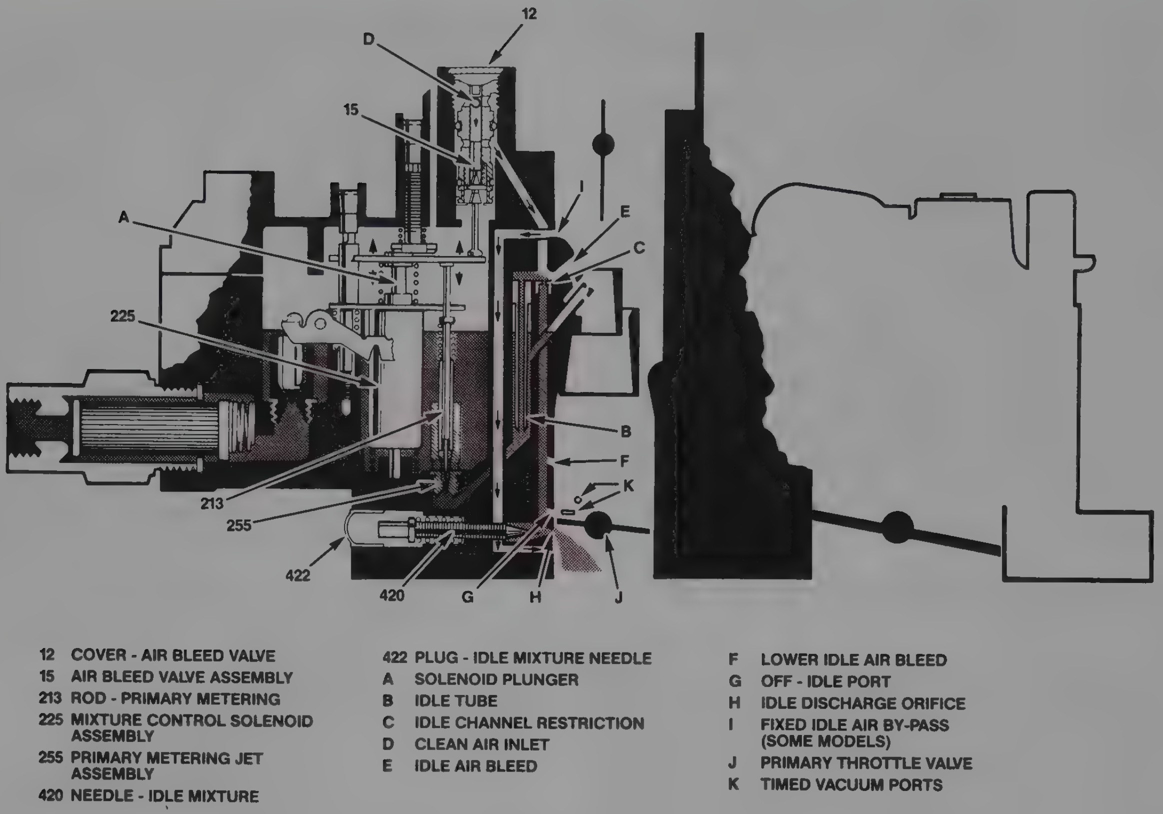

12
D
15
A
225
I
E
C
B
F
K
213
255
422
420
G
H
J
12 COVER - AIR BLEED VALVE
15 AIR BLEED VALVE ASSEMBLY
213 ROD - PRIMARY METERING
225 MIXTURE CONTROL SOLENOID ASSEMBLY
255 PRIMARY METERING JET ASSEMBLY
420 NEEDLE - IDLE MIXTURE
422 PLUG - IDLE MIXTURE NEEDLE
A SOLENOID PLUNGER
B IDLE TUBE
C IDLE CHANNEL RESTRICTION
D CLEAN AIR INLET
E IDLE AIR BLEED
F LOWER IDLE AIR BLEED
G OFF - IDLE PORT
H IDLE DISCHARGE ORIFICE
I FIXED IDLE AIR BY-PASS (SOME MODELS)
J PRIMARY THROTTLE VALVE
K TIMED VACUUM PORTS

Fig. 21-6. Cross-sectional view of a four-barrel, two-stage carburetor showing the idle system. Study the system carefully. (GM)

ADJUSTING IDLE MIXTURE — TWO OR FOUR BARREL CARBURETOR

The adjustment procedure is basically the same as for a single barrel, but two idle mixture screws are used.

Stop the engine after fully warmed. Turn each mixture screw inward until lightly seated. Never seat mixture screws tightly as this will groove the tip and prevent a smooth idle. Back each screw out about one and one-quarter turn.

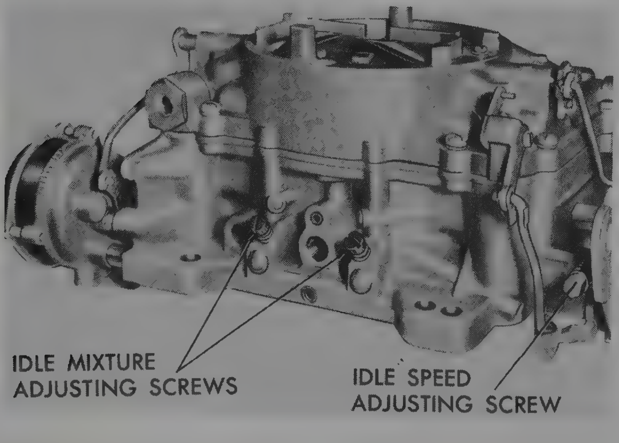

IDLE MIXTURE ADJUSTING SCREWS
IDLE SPEED ADJUSTING SCREW

Fig. 21-7. Idle mixture adjusting screws. (Chevrolet)

Start engine and adjust each screw in or out to produce the highest rpm and vacuum reading. Screws should be adjusted to be within one-quarter to one-half turn of each other. See Figs. 21-6 and 21-7.

ADJUSTING IDLE MIXTURE ON A CARBURETOR EQUIPPED WITH AN IDLE AIR ADJUSTING SCREW

Adjust idle screws as suggested in the preceding paragraph. If idle rpm is altered, move the idle air adjusting screw in (enrichens mixture, slows rpm) or out (leans mixture, increases rpm).

Following movement of the idle air screw, readjust idle mixture screws. Alternate back and forth until both mixture and speed are as specified. Adjust idle mixture screws last. Use as little air as possible to secure the correct idle speed. See Fig. 21-4.

IDLE MIXTURE ADJUSTMENT — INFRA-RED ANALYZER

Idle mixture adjustment is necessary if the carbon monoxide emissions are not within the manufacturer's specifications. Prior to adjusting the idle mixture, the limiter caps must be removed to allow access to the adjusting screws. Limiter caps are installed by the manufacturer to limit the amount of mixture screw

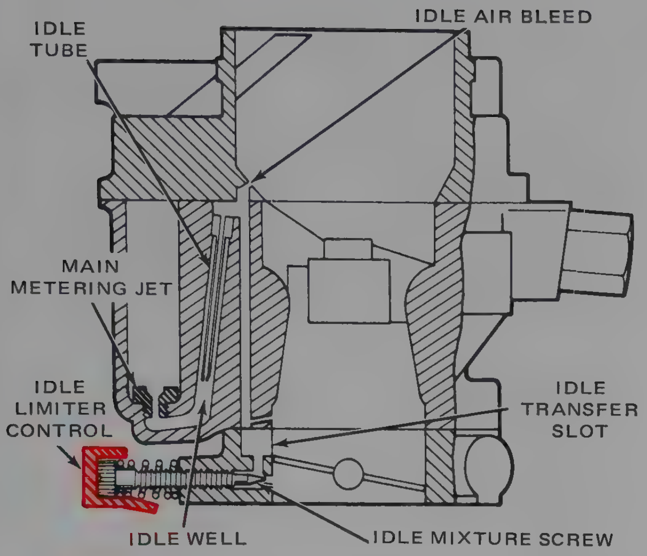

IDLE TUBE
IDLE AIR BLEED
MAIN METERING JET
IDLE LIMITER CONTROL
IDLE TRANSFER SLOT
IDLE WELL
IDLE MIXTURE SCREW

Fig. 21-8. Idle mixture screw adjustment range is limited by idle limiter control cap. (Dodge)

adjustment. The limiter cap shown in Fig. 21-8 permits a small amount of mixture screw adjustment. The locking limiter cap in Fig. 21-9 prevents all adjustment. Some idle mixture screws are recessed into the body of the carburetor and covered with a plug. The plug must be removed to access the idle mixture screws, Fig. 21-10. Many plugs and caps can be removed with the carburetor on the intake manifold, while others require that the carburetor be removed.

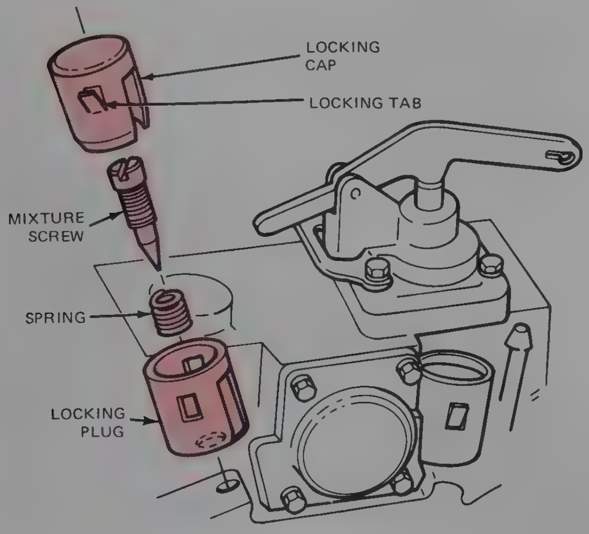

LOCKING CAP
LOCKING TAB
MIXTURE SCREW
SPRING
LOCKING PLUG

Fig. 21-9. One form of idle mixture screw limiter cap. Cap should not be removed unless absolutely necessary. Mixture must be adjusted within specified emission range and caps replaced. (Ford)

Once the limiter caps or plugs are removed, the adjustment screws can be turned to obtain the proper setting. Be sure the engine is at normal operating temperature. Turning the mixture screws should affect engine performance. If not, the carburetor may need cleaning. If the screws must be turned completely in to produce a smooth idle, the carburetor's power valve may be defective. An INFRA-RED analyzer should be used to check the mixture setting. Follow all vehicle and tool manufacturers' operating procedures and precautions so that the REQUIRED emission levels are maintained.

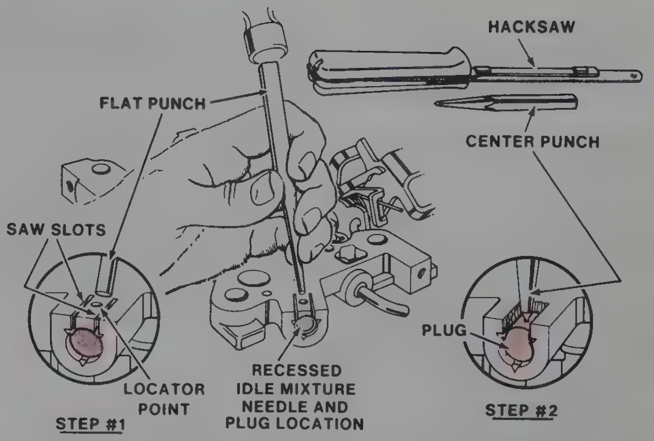

HACKSAW
FLAT PUNCH
CENTER PUNCH
SAW SLOTS
PLUG
LOCATOR POINT
RECESSED IDLE MIXTURE NEEDLE AND PLUG LOCATION
STEP #1
STEP #2

Fig. 21-10. Procedure involved in removing one type of idle mixture screw limiter plug. Avoid heavy hammering! (Chevrolet)

After the idle mixture has been properly adjusted, replace the limiter caps or plugs with new ones.

Be careful to avoid dropping anything into the carburetor when the air cleaner is off. Keep face and

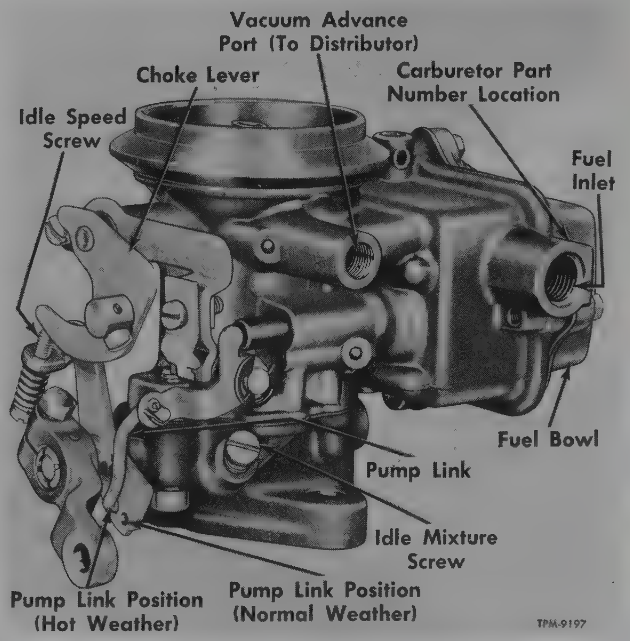

Vacuum Advance Port (To Distributor)
Choke Lever
Carburetor Part Number Location
Idle Speed Screw
Fuel Inlet
Fuel Bowl
Pump Link
Idle Mixture Screw
Pump Link Position (Hot Weather)
Pump Link Position (Normal Weather)
TPM-9197

Fig. 21-11. This carburetor is set up for a manual choke. (G.M.C.)

hands away from the carburetor when the engine is running. A backfire through the carburetor can produce a serious burn.

MANUAL CHOKE ADJUSTMENT

Remove air cleaner. Loosen the choke lever swivel block set screw. Pull the choke knob out about 1/8 in. (3 mm). Tighten control wire clamp. While holding the choke lever so as to force the choke valve into the wide open position, tighten the swivel block set screw on the control wire.

Pull choke knob out. Choke valve should be tightly closed. Push choke knob in. Choke valve should be completely open.

Leaving the choke knob 1/8 in. (3 mm) out before tightening swivel block guarantees that the choke valve will be forced to the wide-open position when the knob is pushed in as far as it will go.

A carburetor set up for manual choke operation is shown in Fig. 21-11.

COLD ENRICHMENT SYSTEM

The cold enrichment system provides the engine with the rich air-fuel mixture necessary for cold starting and driving, Fig. 21-12. Enrichment fuel flow is metered by the tapered cold enrichment rod, which is controlled by a bimetallic choke spring and a control diaphragm. As the engine warms, the cold enrichment rod is lowered until it is seated in a jet at the bottom of the fuel bowl. This will shut off the cold enrichment fuel flow.

AUTOMATIC CHOKE — CLEANING

Remove air cleaner. Note position of the thermostatic spring housing index mark in relation to the choke housing marks. Refer to Fig. 21-13.

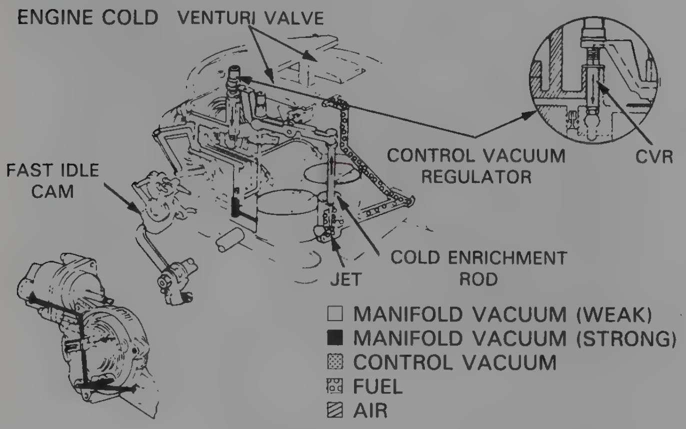

ENGINE COLD
VENTURI VALVE
FAST IDLE CAM
CONTROL VACUUM REGULATOR
CVR
COLD ENRICHMENT ROD
JET
☐ MANIFOLD VACUUM (WEAK)
■ MANIFOLD VACUUM (STRONG)
▨ CONTROL VACUUM
▨ FUEL
▨ AIR

Fig. 21-12. Typical cold enrichment system. The fast idle cam, venturi valve, and fuel flow are controlled by the choke cap and the choke diaphragm. (Ford)

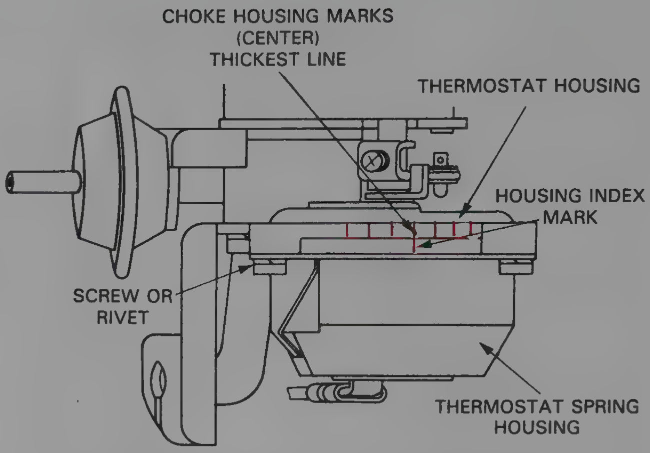

CHOKE HOUSING MARKS (CENTER) THICKEST LINE
THERMOSTAT HOUSING
HOUSING INDEX MARK
SCREW OR RIVET
THERMOSTAT SPRING HOUSING

Fig. 21-13. Note alignment of index marks before removing choke spring housing. (Chevrolet)

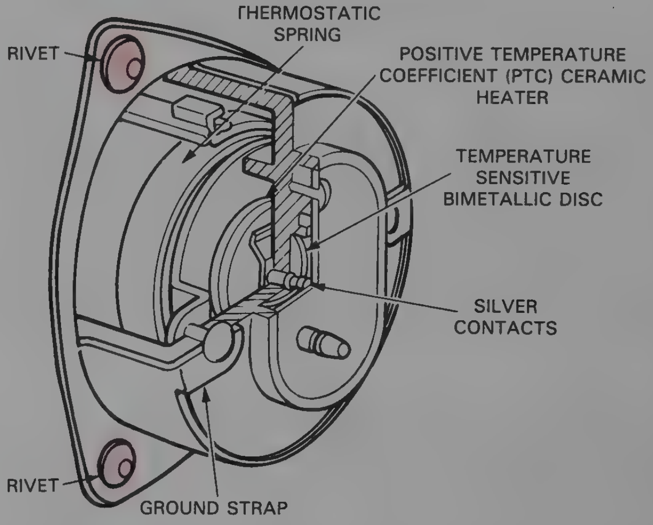

RIVET
THERMOSTATIC SPRING
POSITIVE TEMPERATURE COEFFICIENT (PTC) CERAMIC HEATER
TEMPERATURE SENSITIVE BIMETALLIC DISC
SILVER CONTACTS
RIVET
GROUND STRAP

Fig. 21-14. This choke cover is secured with rivets. Remove by drilling out. Note electric heating unit. (Ford)

Remove the choke cover, thermostatic spring, and related parts. If the cover is secured with rivets, they may be drilled out, Fig. 21-14.

ELECTRIC ASSIST CHOKE

Clean metallic parts in recommended cleaner and blow dry. Do not wash electrical parts. Be careful not to distort the thermostatic spring. See Fig. 21-15.

While moving the choke valve, apply a few drops of clean carbon solvent to the choke shaft bearings and the external linkage. If linkage is quite dirty, use a small brush to work the dirt off.

Inspect the inside of the thermostat spring housing. If dirty, remove the choke piston and lever for cleaning. Remove the hot air tube from the choke stove and blow out with air. Blow out stove clean air inlet tube where used. Fig. 21-16 illustrates one type of choke hot air

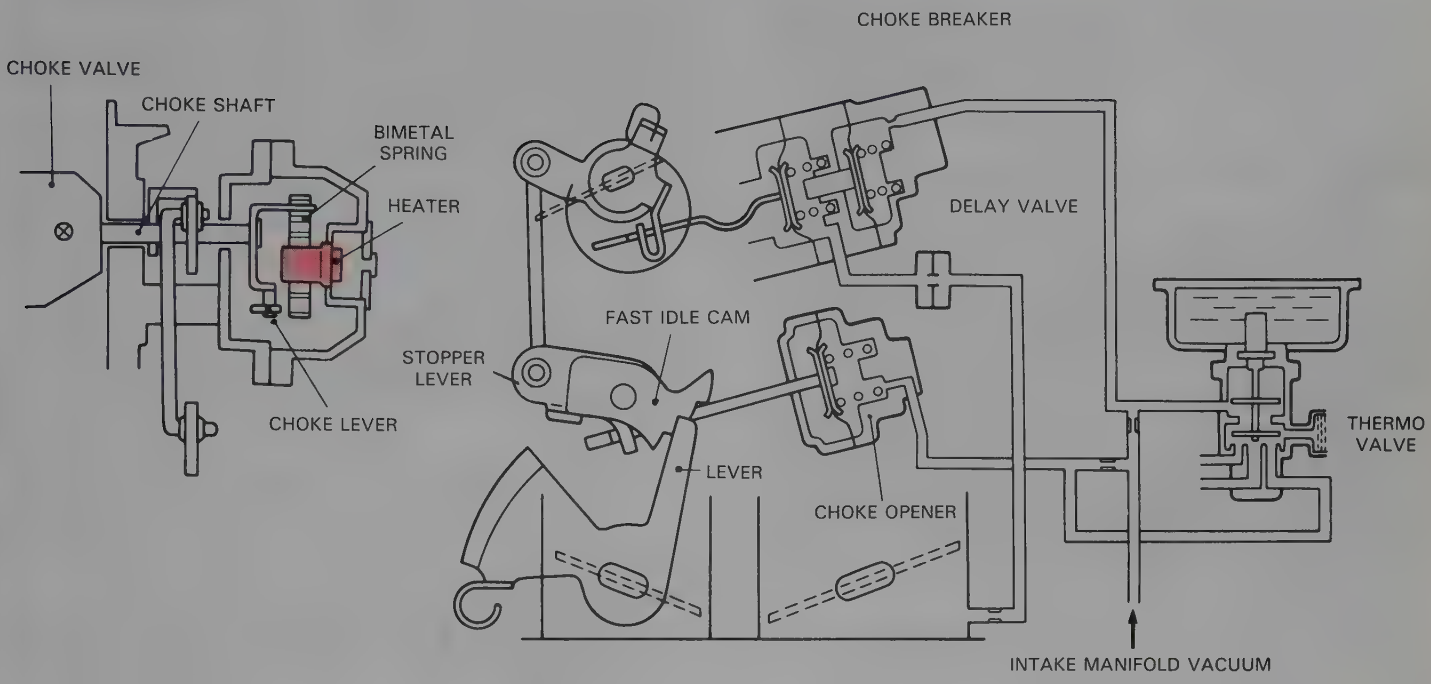

CHOKE BREAKER
CHOKE VALVE
CHOKE SHAFT
BIMETAL SPRING
HEATER
DELAY VALVE
FAST IDLE CAM
STOPPER LEVER
CHOKE LEVER
THERMO VALVE
LEVER
CHOKE OPENER
INTAKE MANIFOLD VACUUM

Fig. 21-15. An overall view of one type of electric choke system. The electric heater in this choke assembly is controlled by the electronic control unit. (Dodge)

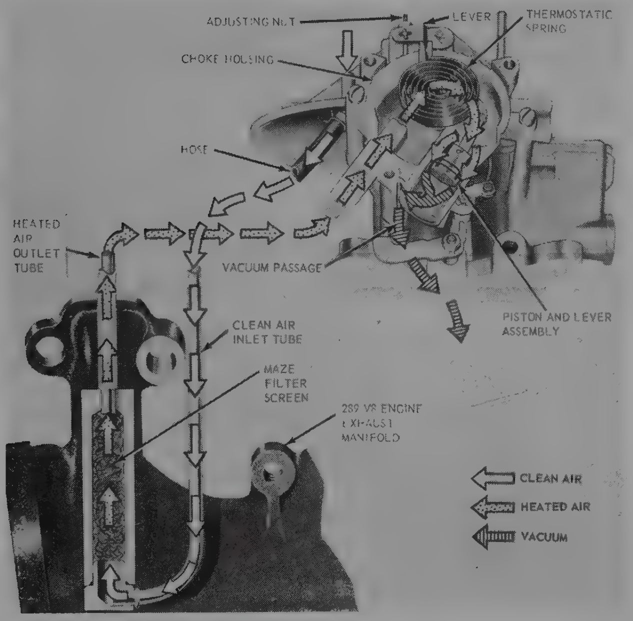

ADJUSTING NUT
LEVER
THERMOSTATIC SPRING
CHOKE HOUSING
HOSE
HEATED AIR OUTLET TUBE
VACUUM PASSAGE
PISTON AND LEVER ASSEMBLY
CLEAN AIR INLET TUBE
MAZE FILTER SCREEN
289 V8 ENGINE EXHAUST MANIFOLD
CLEAN AIR
HEATED AIR
VACUUM

Fig. 21-16. This choke hot air system is designed to provide CLEAN air. (Ford)

supply system. Note clean air hose.

Reassemble all choke parts. Use a new cover gasket. Make certain the thermostatic spring is positioned correctly and that it engages the choke shaft lever. Align the housing and cover index marks and tighten cover fasteners securely.

WATER HEATED CHOKE

The choke illustrated in Fig. 21-17 uses engine coolant to warm the air around the thermostatic spring.

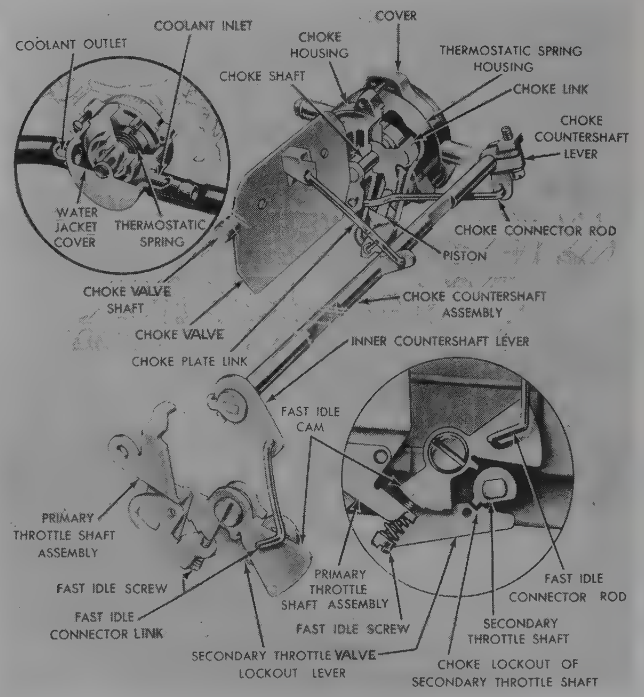

COOLANT OUTLET
COOLANT INLET
CHOKE HOUSING
COVER
THERMOSTATIC SPRING HOUSING
CHOKE SHAFT
CHOKE LINK
CHOKE COUNTERSHAFT LEVER
WATER JACKET COVER
THERMOSTATIC SPRING
CHOKE CONNECTOR ROD
PISTON
CHOKE VALVE SHAFT
CHOKE COUNTERSHAFT ASSEMBLY
CHOKE VALVE
INNER COUNTERSHAFT LEVER
CHOKE PLATE LINK
FAST IDLE CAM
PRIMARY THROTTLE SHAFT ASSEMBLY
FAST IDLE SCREW
FAST IDLE CONNECTOR LINK
PRIMARY THROTTLE SHAFT ASSEMBLY
FAST IDLE SCREW
FAST IDLE CONNECTOR ROD
SECONDARY THROTTLE SHAFT
SECONDARY THROTTLE VALVE LOCKOUT LEVER
CHOKE LOCKOUT OF SECONDARY THROTTLE SHAFT

Fig. 21-17. This automatic choke uses engine coolant to heat the air surrounding the thermostatic coil spring. (Ford)

Check coolant hoses for leakage. No choke stove or hot air pipes are needed. Clean choke parts and linkage.

Choke function requires a properly operating thermostat.

REMOTE THERMOSTATIC SPRING

The choke system shown in Fig. 21-18 places the thermostatic spring actuating device directly in a choke stove or well. The stove, in this case, is located in the intake manifold, directly over the hot exhaust crossover passage.

This setup also uses a vacuum diaphragm choke "break," instead of a choke vacuum piston "break," to assist in properly positioning the choke valve during warmup. Look at Fig. 21-18. Some setups provide extra heat for the choke spring with an electrically heated unit. This assists in rapid opening under certain conditions.

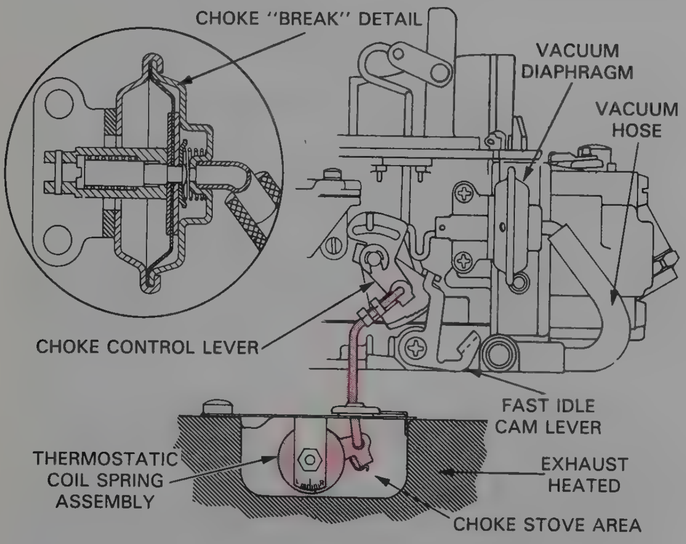


Fig. 21-18. Remotely located thermostatic coil spring actuating device. This is often referred to as a "divorced" choke. Note use of vacuum diaphragm choke break. (Colt Industries)

ADJUSTING AUTOMATIC CHOKE THERMOSTATIC SPRING TENSION

The tension applied to the thermostatic spring is determined by the positioning of the choke housing and cover index marks. Align marks as recommended by the manufacturer. This initial setting, although usually very close, may require a slight adjustment after trying out choke operation. The cover will be marked indicating the direction in which to turn for a LEAN or a RICH setting.

Hard starting, sputtering, spitting, and coughing during warmup may indicate the need of a RICHER SETTING. Engine loping and black smoke from the exhaust indicate the need for a LEANER SETTING.

Remember the choke valve should be closed with the engine cold and wide open with the engine hot (normal operating temperature).

The choke in Fig. 21-19 is adjusted one notch LEAN.

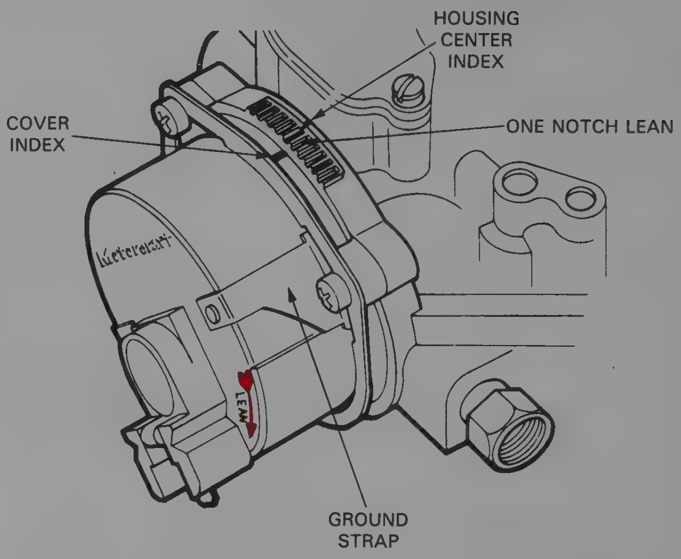


Fig. 21-19. This particular application specifies an initial setting one notch (index mark) on LEAN side. On some electric chokes, a ground circuit is completed via a metal plate placed at back of choke cover unit. On these, do not use a gasket at this point in that it would break circuit. (Ford)

The remotely located choke thermostatic spring control adjusts somewhat differently. The choke in Fig. 21-20 is adjusted by loosening locknut A and turning post with a screwdriver until index mark on B is aligned as desired. Lock by holding post with a screwdriver and tightening locknut A. Pull up cover C and make sure control rod has clearance on both open and closed positions.

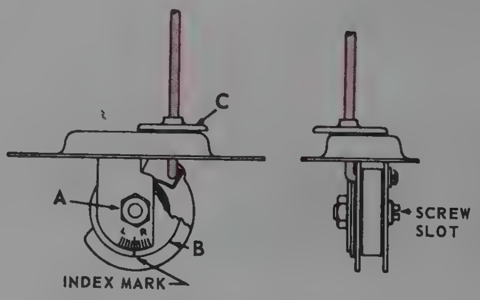


Fig. 21-20. Remote choke thermostatic spring tension adjustment device. (G.M.C.)

Some chokes have no provision for adjustment and if defective, parts must be replaced.

CHOKE VACUUM "BREAK"

The choke valve position during warmup is determined by incoming air pressure on the offset choke valve. Incoming air attempts to open the choke. The pull of the vacuum piston or diaphragm also attempts to open the choke. The pressure of the thermostatic spring attempts to close the choke. This opening action by the vacuum piston or diaphragm is referred to as "kick," "break," or "unloading."

The choke vacuum "break" requires an accurate relationship between the position of the vacuum piston and the choke valve. Adjustment is provided so that a proper setting may be made.

SETTING CHOKE VACUUM "BREAK" (PISTON TYPE)

Remove the thermostatic spring cover and spring. Block the throttle half open. Move the vacuum piston to the specified position by using a wire gauge as shown in Figs. 21-21 and 21-22.

While the piston is held in this position, exert light pressure on the choke valve (in the closing direction) to eliminate linkage slack. Slip a gauge of specified size between the edge of the choke valve and the air horn. Gauge should enter with a very light drag.

If the gauge indicates improper clearance between the valve and the air horn wall, adjust as directed. Fig. 21-21 shows the procedure. The choke "break" is set with an adjusting nut on this particular carburetor.

Other methods of adjustment include bending the linkage or loosening and repositioning the choke shaft lever on the shaft. See Fig. 21-22.

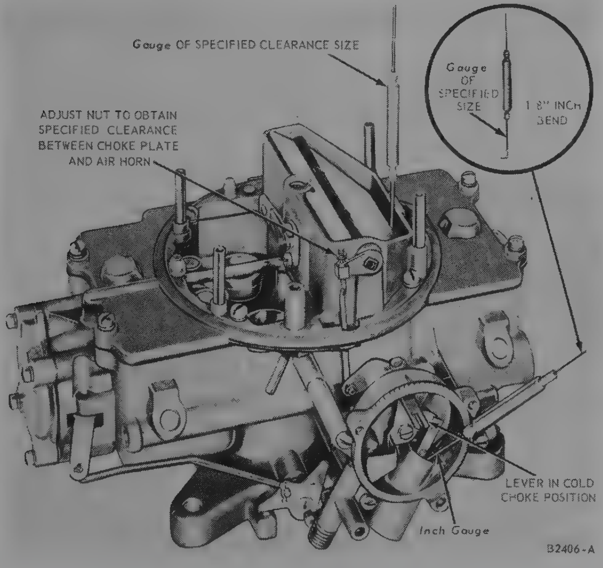

Gauge OF SPECIFIED CLEARANCE SIZE
ADJUST NUT TO OBTAIN SPECIFIED CLEARANCE BETWEEN CHOKE PLATE AND AIR HORN
Gauge OF SPECIFIED SIZE
1/8" INCH BEND
LEVER IN COLD CHOKE POSITION
Inch Gauge
B2406-A

Fig. 21-21. Making a choke break adjustment. (Ford)

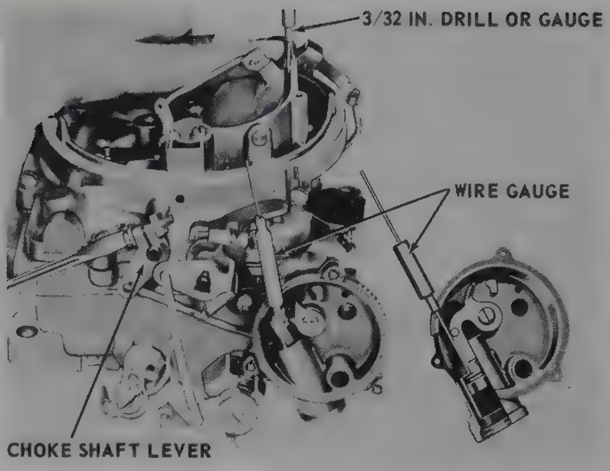

3/32 IN. DRILL OR GAUGE
WIRE GAUGE
CHOKE SHAFT LEVER

Fig. 21-22. On this carburetor, choke vacuum break setting is adjusted by loosening and repositioning choke shaft lever. Note how choke piston (cutaway inset) is positioned with wire gauge.

VACUUM BREAK SETTING (DIAPHRAGM TYPE)

The vacuum break diaphragm in Fig. 21-23 is adjusted by forcing the diaphragm rod inward until it reaches the bottom. While holding it in this position, the clearance between choke valve and air horn wall is measured.

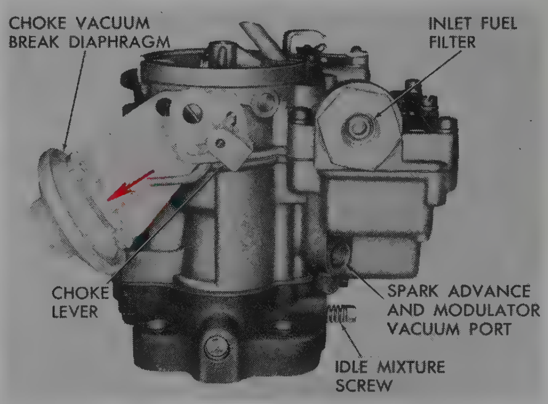

CHOKE VACUUM BREAK DIAPHRAGM
INLET FUEL FILTER
CHOKE LEVER
SPARK ADVANCE AND MODULATOR VACUUM PORT
IDLE MIXTURE SCREW

Fig. 21-23. Choke break vacuum diaphragm must be held IN while clearance between choke valve and air horn is checked. (Chevrolet)

THROTTLE CHOKE VALVE (WIDE-OPEN) BREAK OR UNLOADER ADJUSTMENT

Move the throttle to the wide-open position. Throttle lever tang will strike the fast idle cam, causing the choke valve to be partially opened. While holding the throttle in the wide-open position, check clearance between choke valve and air horn wall. Bend tang to secure correct opening. Do not bend link as this will upset the fast idle cam adjustment. See Fig. 21-24.

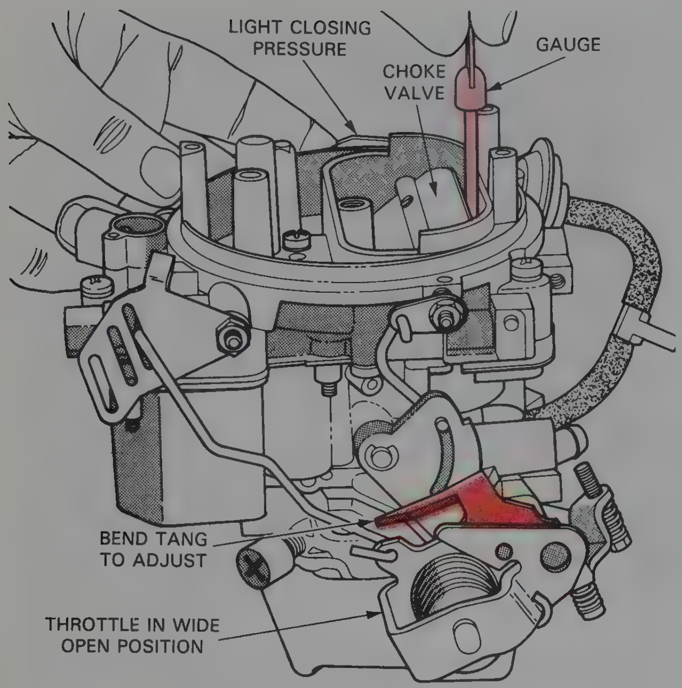

LIGHT CLOSING PRESSURE
GAUGE
CHOKE VALVE
BEND TANG TO ADJUST
THROTTLE IN WIDE OPEN POSITION

Fig. 21-24. Choke throttle break or unloader adjustment. Note special gauge placed between choke valve and air horn wall. (Plymouth)

ANTI-STALL DASHPOT ADJUSTMENT (EXTERNAL TYPE)

Move the throttle to the fully closed (hot idle) position. Make sure fast idle cam is not holding throttle partially open. While holding throttle in the full-closed position, push the dashpot plunger rod away from the throttle contact area as far as possible. Measure the distance between plunger and throttle contact. Adjust dashpot (or dashpot plunger in some cases) to provide specified clearance. See Fig. 21-25.

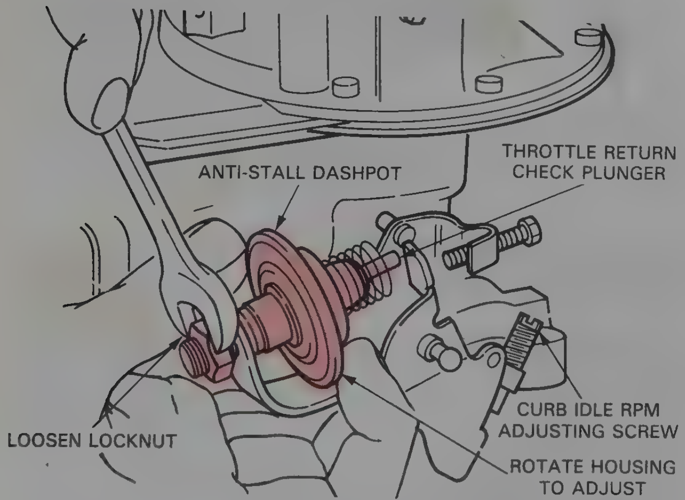

ANTI-STALL DASHPOT
THROTTLE RETURN CHECK PLUNGER
LOOSEN LOCKNUT
CURB IDLE RPM ADJUSTING SCREW
ROTATE HOUSING TO ADJUST

Fig. 21-25. Adjusting an anti-stall dashpot. (Ford)

ANTI-STALL DASHPOT ADJUSTMENT (INTERNAL TYPE)

Adjust operating lever to produce required measurement.

The internal dashpot is built as a part of the carburetor. It uses a piston (plunger) or a diaphragm to move fuel through an orifice. This develops a hydraulic retarding force, as shown in Fig. 21-26. It has two adjustments. One is for closed (hot idle) throttle and one is for wide-open throttle.

The anti-stall dashpot in Fig. 21-27 uses a diaphragm to move fuel as a retarding force. Note adjusting screw.

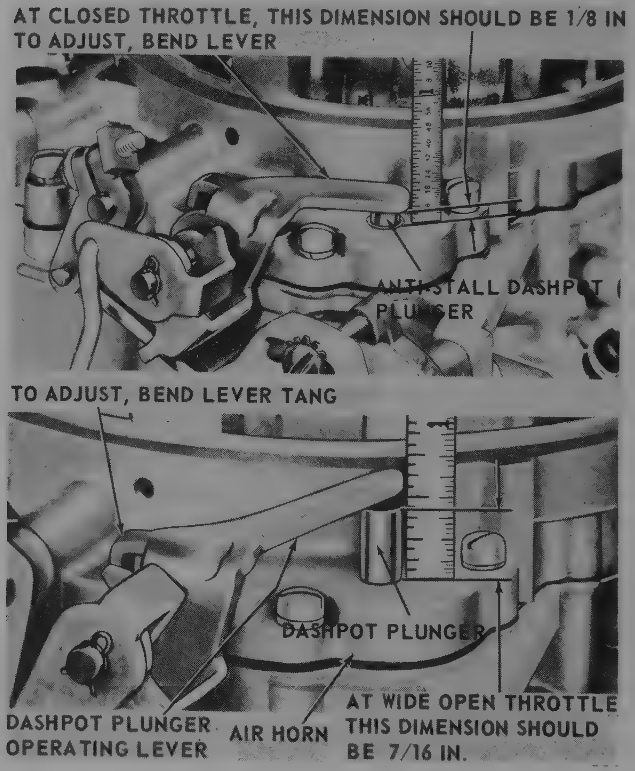

AT CLOSED THROTTLE, THIS DIMENSION SHOULD BE 1/8 IN
TO ADJUST, BEND LEVER
ANTI-STALL DASHPOT PLUNGER
TO ADJUST, BEND LEVER TANG
DASHPOT PLUNGER
DASHPOT PLUNGER OPERATING LEVER
AIR HORN
AT WIDE OPEN THROTTLE THIS DIMENSION SHOULD BE 7/16 IN.

Fig. 21-26. One type of internal anti-stall dashpot adjustment.

DASHPOT ACTION CHECK

When the dashpot is actuated, it should move slowly and with resistance. If it fails to do this, repair or replace as required.

ACCELERATOR PUMP ADJUSTMENT

Close the throttle and check the position of the accelerator pump rod, link, or lever, etc., in relation to a specified portion of the carburetor. Bend link or lever as required. Fig. 21-28 shows a typical pump link. Also shown are two holes in the tang of the operating lever.

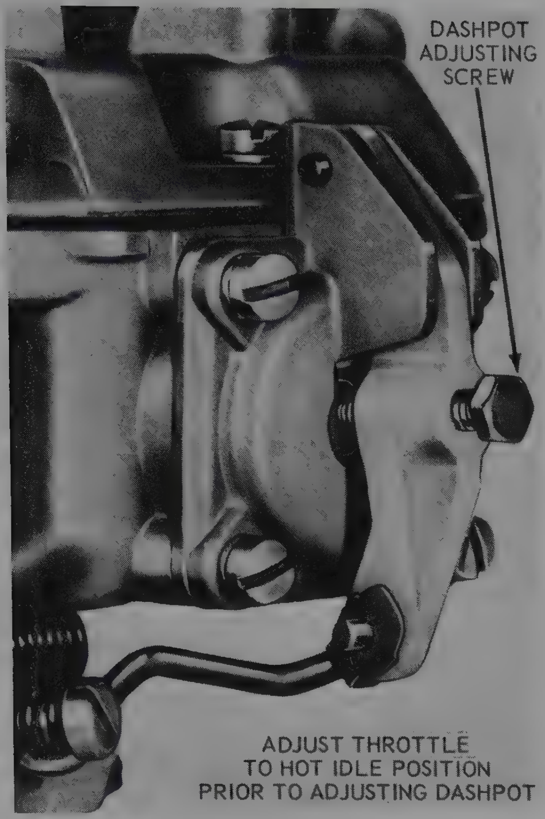

DASHPOT ADJUSTING SCREW
ADJUST THROTTLE TO HOT IDLE POSITION PRIOR TO ADJUSTING DASHPOT

Fig. 21-27. Internal diaphragm type anti-stall dashpot. Note adjustment screw. (Ford)

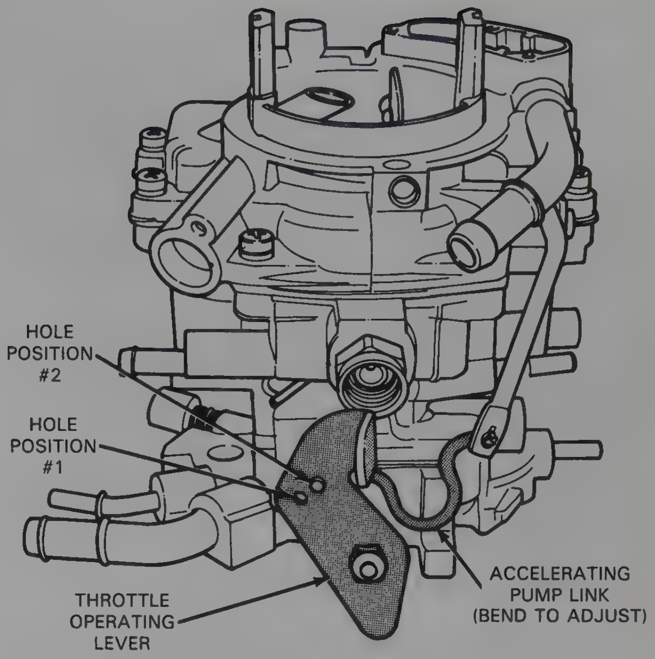

HOLE POSITION #2
HOLE POSITION #1
THROTTLE OPERATING LEVER
ACCELERATING PUMP LINK (BEND TO ADJUST)

Fig. 21-28. Accelerator pump link can be placed in one of two throttle lever holes. Link is often bent to secure a specific setting. (Dodge)

By placing the rod in different holes, the pump stroke and amount of gasoline delivered to the air horn can be varied.

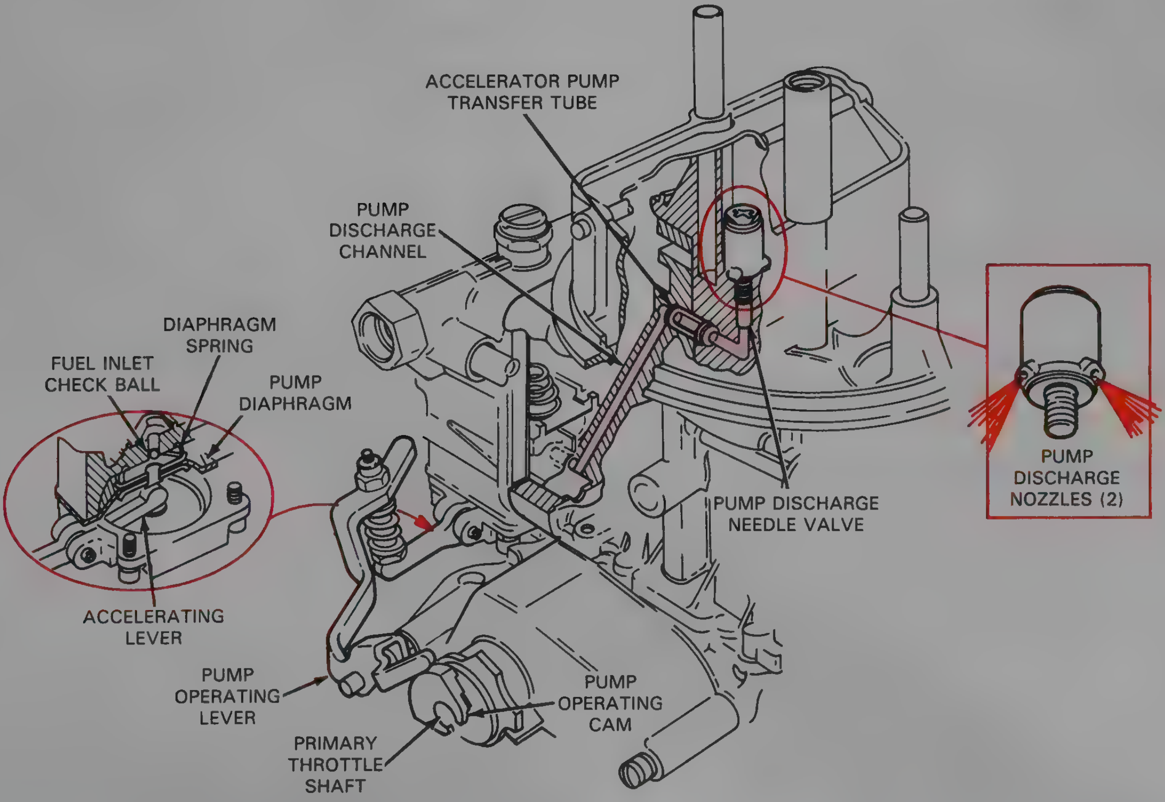

ACCELERATOR PUMP TRANSFER TUBE
PUMP DISCHARGE CHANNEL
DIAPHRAGM SPRING
FUEL INLET CHECK BALL
PUMP DIAPHRAGM
ACCELERATING LEVER
PUMP OPERATING LEVER
PRIMARY THROTTLE SHAFT
PUMP OPERATING CAM
PUMP DISCHARGE NEEDLE VALVE
PUMP DISCHARGE NOZZLES (2)

Fig. 21-29. Cutaway of accelerating pump system. This system uses a diaphragm type pump. (Ford)

QUICK ACCELERATOR PUMP CHECK

Remove the air cleaner. Open the throttle, from idle to full open (engine stopped) quickly, while observing the pump discharge nozzle in the air horn. Depending on pump nozzle design, one or more streams of gas should be evident. The fine gas stream should be strong and should last for a short time even after the throttle reaches full open.

If little or no gas output is noticed, the accelerator pump piston leather (or diaphragm, if of that type) could be cracked or worn. Check valves can be stuck open by dirt or the discharge nozzle feed system can be clogged. Clean and repair as needed.

The cutaway carburetor, Fig. 21-29, shows one type of diaphragm-operated accelerating pump system.

FUEL BOWL VENT ADJUSTMENT

Some older carburetors vent the fuel bowl to the atmosphere. Modern closed fuel systems vent to the air horn and/or to the emission control vapor storage canister.

Check the linkage adjustment as directed. Fig. 21-30 shows the vent actuating setup on one carburetor.

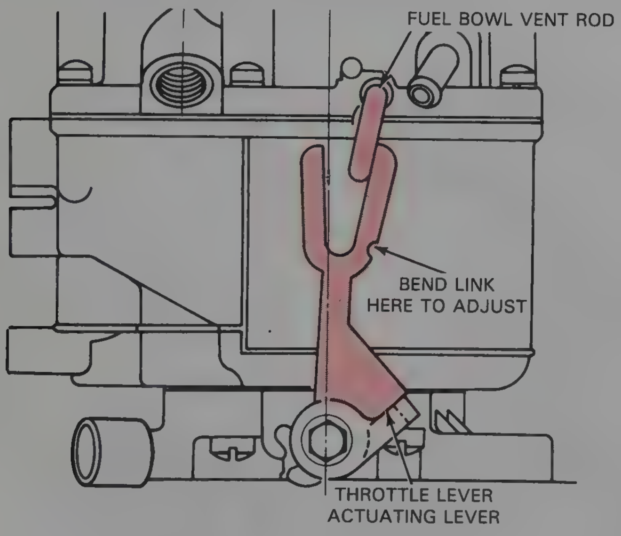

FUEL BOWL VENT ROD
BEND LINK HERE TO ADJUST
THROTTLE LEVER
ACTUATING LEVER

Fig. 21-30. Fuel bowl vent actuating linkage. (Ford)

CHECKING AND SETTING FLOAT LEVEL

The float level setting is CRITICAL in that it establishes the height of the fuel in the bowl. See Fig. 21-31.

A higher than specified fuel level will result in poor gas mileage, spark plug fouling, crankcase dilution, and all-around poor performance. A low fuel level will cause spitting, bucking, and loss of power.

Float level is checked by either measuring from some portion of the float to the cover, use of an inspection plug, or by using a gauge. Figs. 21-32 and 21-33 show gauges designed for the purpose. Adjust level by careful bending of the float arm.

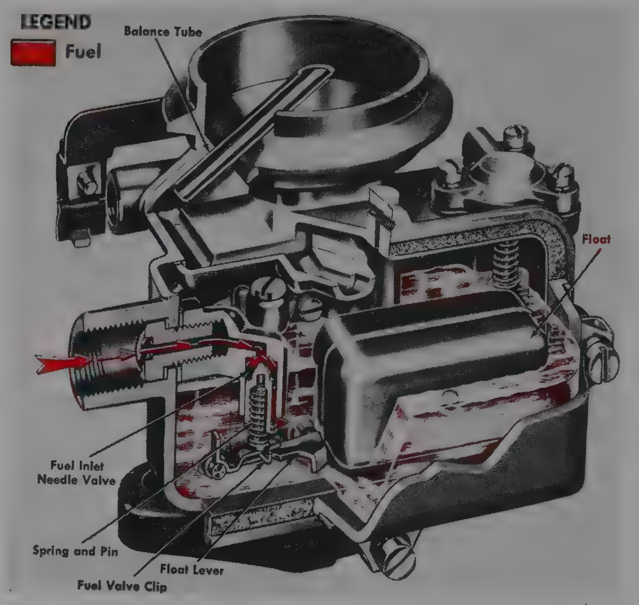

LEGEND
🟥 Fuel
Balance Tube
Float
Fuel Inlet Needle Valve
Spring and Pin
Float Lever
Fuel Valve Clip

Fig. 21-31. Float level determines the height of the fuel in the bowl. (G.M.C.)

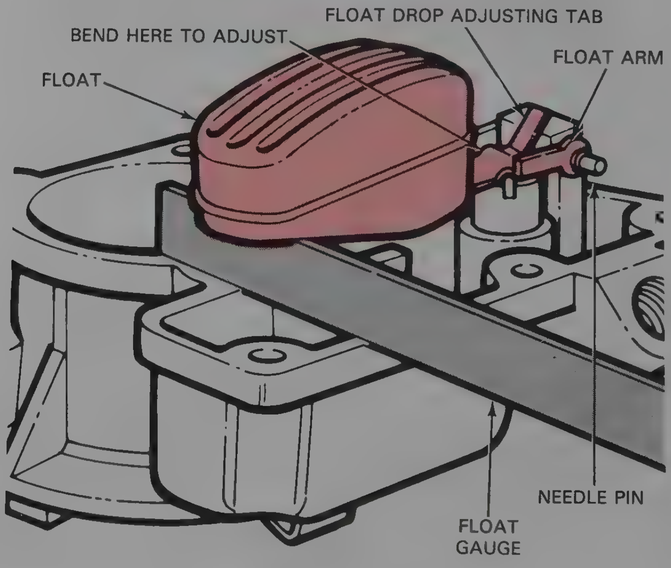

FLOAT DROP ADJUSTING TAB
BEND HERE TO ADJUST
FLOAT ARM
FLOAT
NEEDLE PIN
FLOAT GAUGE

Fig. 21-32. Using a special gauge to check float height or level. (Ford)

CHECKING AND SETTING FLOAT DROP

A float drop setting may be checked with a gauge or by measuring between two specified points. Adjust by careful bending of the float stop tab or lip. See Fig. 21-34.

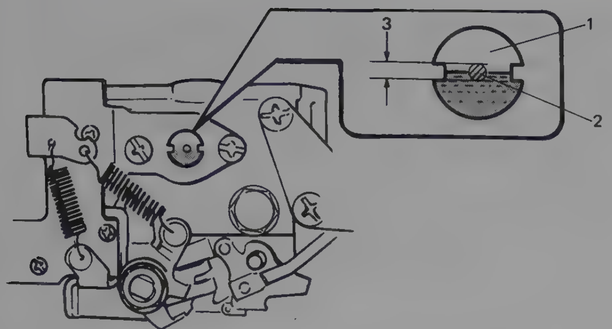


Fig. 21-33. A glass fuel bowl inspection port is used to check for proper fuel level in the float bowl. 1—Level gauge. 2—Round mark. 3—Fuel level (correctly located between lines). (Suzuki)

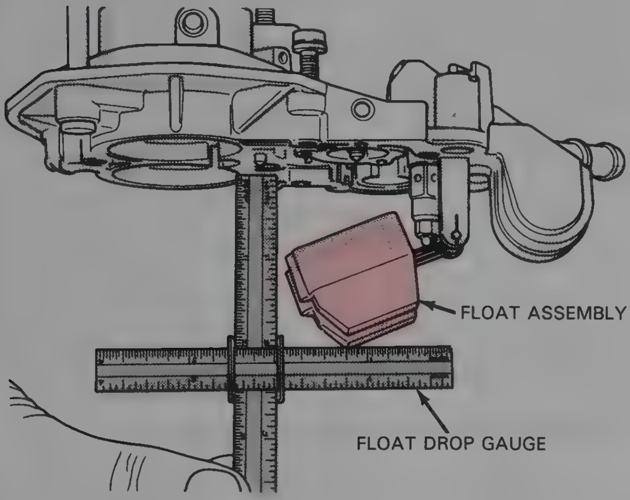


Fig. 21-34. Measuring float drop. Be careful in handling unit to prevent springing or bending float. (Chrysler)

When adjusting, be careful to bend where indicated. Make certain the float is not twisted or bent sideways. If it is, it may hang up on the bowl walls.

ADJUSTING FLOAT BY MOVING ADJUSTABLE INLET SEAT

Another method of adjusting the float level on some carburetors is to move an adjustable inlet or float needle seat. Fig. 21-35 illustrates the method involved in setting this particular float. Note the adjusting nut and lock screw.

CHECKING ACTUAL FUEL LEVEL IN BOWL

The float level and drop settings provide a basic "dry" setting. It is often necessary to check the actual level ("wet" setting) of the fuel in the bowl.

This can be done by running the engine until warm, stopping and measuring the distance from a specified point to the fuel level. This is shown in Fig. 21-36.

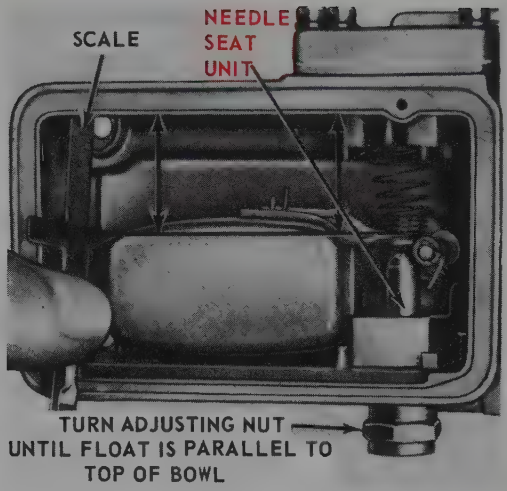


Fig. 21-35. Adjust float level by moving inlet needle seat in or out. (Ford)

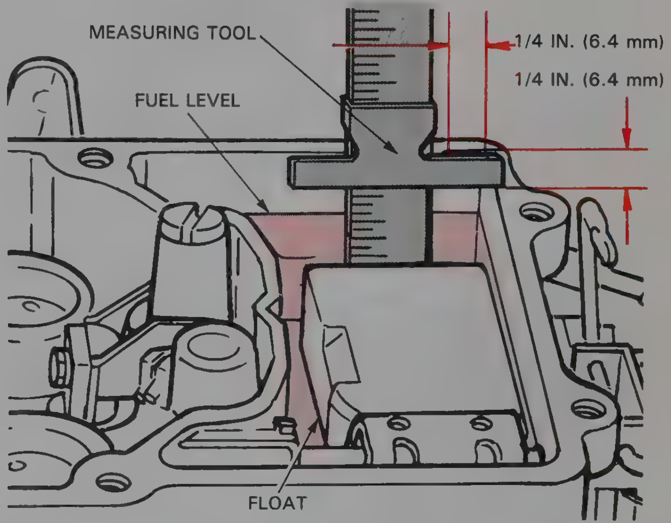


Fig. 21-36. Using steel rule to check fuel "wet" level in bowl. Wet setting checks can be dangerous. Be careful of fire! (Ford)

Fig. 21-37 shows the use of a special test gauge to check "wet" float level. Tool has a tube that is inserted into one float bowl vent stack. When fuel is siphoned from bowl by squeezing primer, fuel will reach a level in the sight tube. A scale shows correct height. This test is conducted with the engine warm and running.

Another method utilizes a "sight plug" in the end of the bowl. The plug is removed and the fuel level determined by the relationship between the fuel level height and the bottom of the hole.

The float must be readjusted to provide the exact fuel level required. When checking, the car must be level, engine at normal operating temperature, fuel pump pressure normal, and the inlet needle must not be leaking.

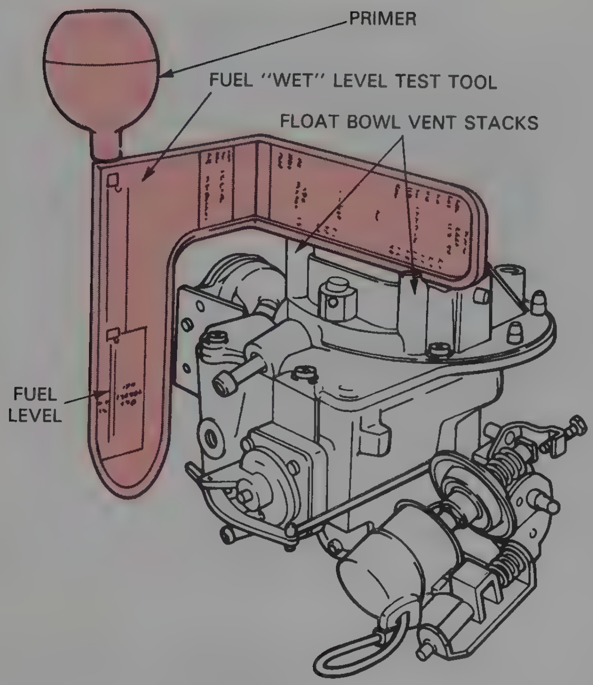


Fig. 21-37. Using a special gauge to check fuel level wet setting. Tool has a hollow tube that is inserted into one of the float bowl vent stacks. Priming will cause fuel to seek its level on gauge scale. Use as directed. (Ford)

Where an adjustable needle seat is used, the float "wet" adjustment is easy. Warm engine, then turn it off. Remove sight plug and check level. If too low, hold adjusting nut and loosen lockscrew. Turn nut out (counterclockwise) to raise fuel level. Tighten lockscrew. Replace sight plug. Start engine and run for a minute. Stop. Remove sight plug and recheck. Repeat until level is exact.

NEVER LOOSEN THE LOCKSCREW OR OPEN THE SIGHT PLUG WHEN THE ENGINE IS RUNNING!

If the fuel level is too high, lower below specified level and then raise to height required.

REPLACE FUEL INLET SEAT AND NEEDLE

The fuel bowl inlet needle and seat eventually wear and start to leak. Replace seat and needle as a matched set.

HANDLE WITH CARE. The carburetor float system is delicate and can be severely damaged by improper handling.

NOTE: The float must be airtight. Occasionally a float will leak and admit gas. This will cause it to sink and become useless. Always shake the float to test for gasoline inside. If gas is "sloshing" around, replace the float.

A more accurate test can be made quickly by submerging the float in cool, clear water. Slowly heat water to just below the boiling point. This will warm the air inside the float, creating a mild pressure that will force air through any crack. The air, in the form of bubbles, will be easily visible.

VARIABLE VENTURI OPENING CHECK

Some carburetors employ a variable venturi valve that alters the size of the venturi opening to meet

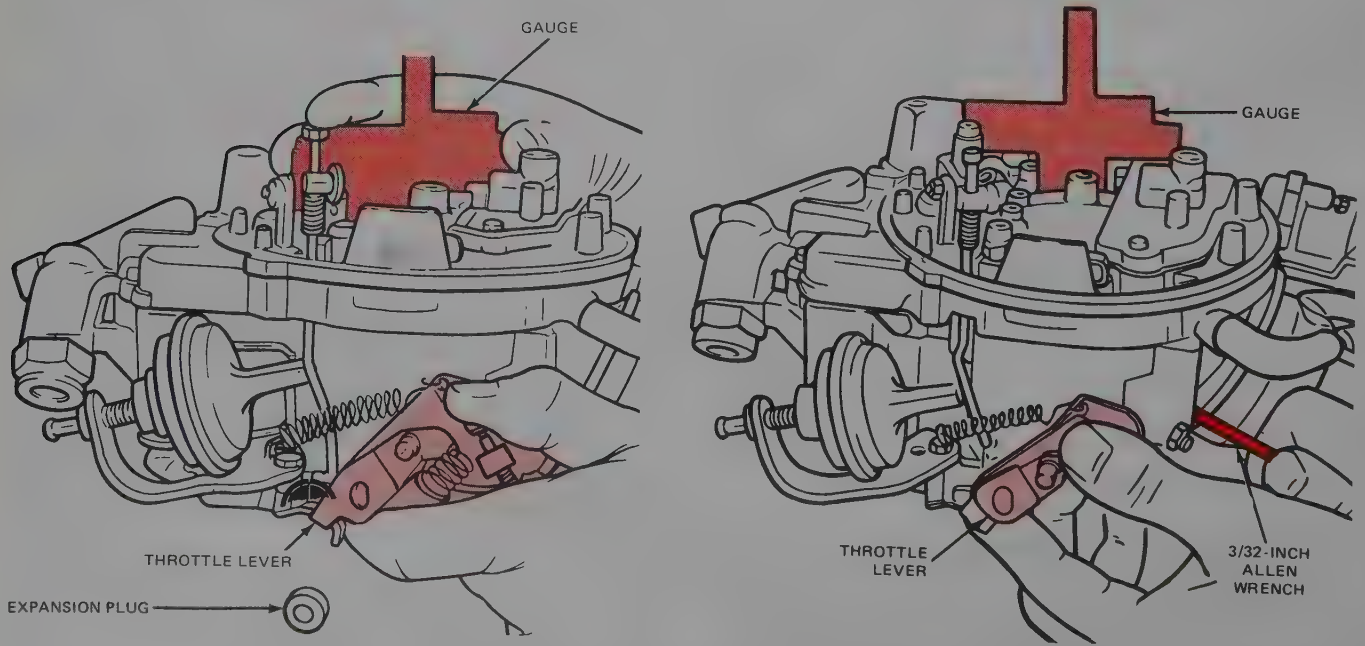


Fig. 21-38. A—Checking venturi valve maximum opening. Note gauge. B—Adjusting venturi valve maximum opening clearance with Allen wrench. (Ford)

various engine speed and load conditions.

A common check and adjustment concerns the maximum venturi valve opening at the wide open throttle position. Fig. 21-38 illustrates both checking and adjusting this opening. In A, mechanic is holding the throttle in the wide open position while checking gap between venturi opening wall and valve. In B, gap is being adjusted by turning venturi limiter adjustment screw. Look at Fig. 21-38.

MIXTURE CONTROL SOLENOID CHECK

A number of carburetors utilize an electrically operated mixture control solenoid. The mixture solenoid is pulsed (opened or closed) by a signal from an electronic module (computer).

The control solenoid can be checked for proper operation (freedom from binding and leaking) by using the test tool shown in Fig. 21-39. Follow the manufacturer's recommended test procedure.

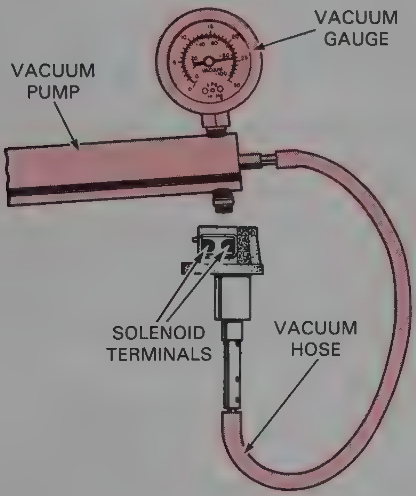


Fig. 21-39. Using special vacuum pump to check fuel mixture control solenoid operation. (Chevrolet)

ALTITUDE COMPENSATION

Carburetors are sometimes equipped with an altitude compensating device. An aneroid is used to operate an air valve. An aneroid is a sealed bellows with a partial vacuum that expands with a drop in barometric pressure and contracts with a pressure increase. As the altitude increases, the aneroid capsule forces an air valve open and admits additional air to the fuel mixture. High elevations provide less oxygen per unit of air. By adding additional amounts of air, the oxygen-fuel ratio is closely maintained.

Set altitude compensator as specified by manufacturer, Fig. 21-40.

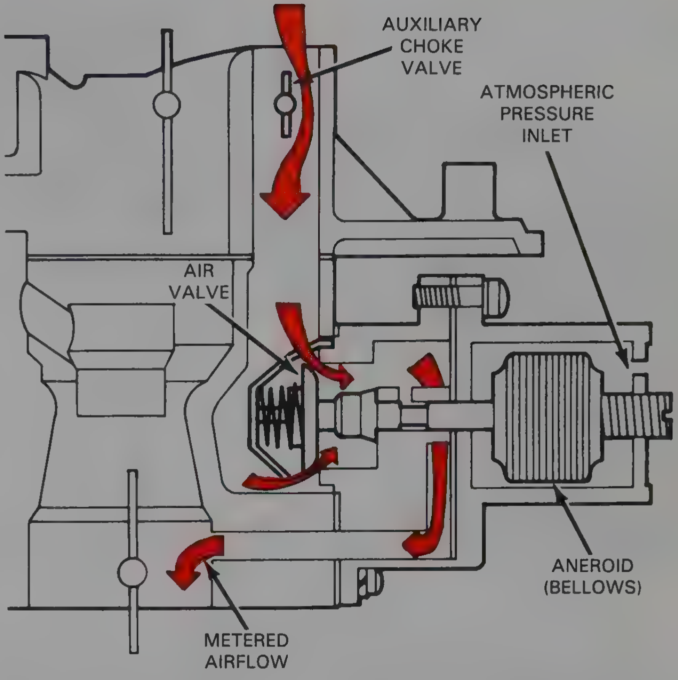


Fig. 21-40. Cutaway showing aneroid operated altitude compensating system. As elevation increases, aneroid expands thus opening air valve and admitting extra air to fuel mixture. (AMC)

OTHER CARBURETOR ADJUSTMENTS

Other carburetor adjustments, in addition to those covered, are needed on some carburetors. These include secondary throttle opening point, secondary throttle choke lockout, auxiliary throttle plate, metering valve, altitude compensator, throttle position sensor, idle speed up (solenoid or vacuum operated), and anti-diesel solenoid. To insure complete and accurate work, always use a service manual covering the EXACT carburetor being serviced.

CARBURETOR DISASSEMBLY, CLEANING, AND INSPECTION

Attach repair legs to the carburetor to prevent damage to throttle plates or valves. See Fig. 21-41.

Use a sharp scriber to mark parts before disassembly. If jets are to be removed, mark jet and adjacent area. Note how a scriber is being used to mark throttle valves for both location and positioning on the shaft, Fig. 21-42.

Following disassembly, soak all parts except those made of rubber, leather, fabric, or fiber (electrical parts, power valve, accelerator pump plunger, anti-stall dashpot, diaphragm units, fuel enrichment valve, plastic float) in clean carburetor cleaner. Soak for the recommended time. Remove, rinse as directed, and blow dry. Wipe parts not soaked in cleaner with a clean cloth.

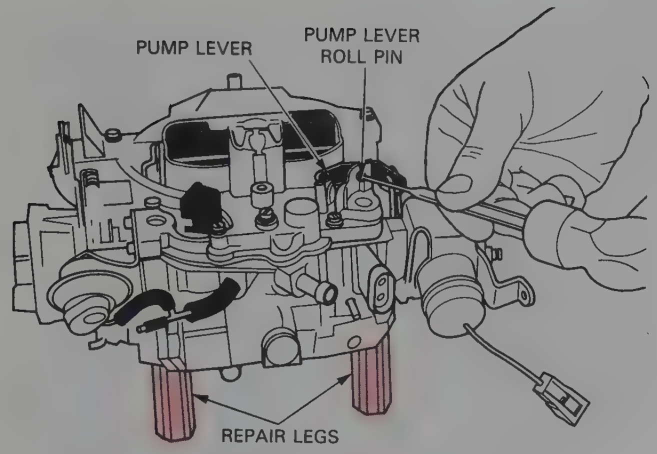


Fig. 21-41. Carburetor mounted on repair legs greatly facilitates overhaul and prevents damage to throttle plates. (Cadillac)

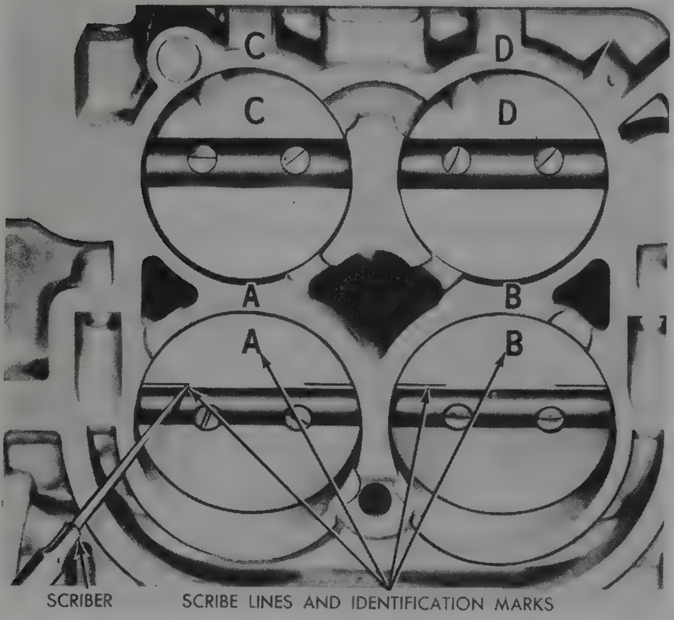


Fig. 21-42. Mark parts with a scriber before disassembly. (Lincoln)

Blow out all passageways. Never use a wire or drill to probe into jets, air bleeds, or other passages. To prevent damage, use the air blast only. Do not direct air blast into any diaphragm units.

Inspect all parts for cracks. Check all parting surfaces for nicks and burrs. Examine choke and throttle shafts and bearings for excessive looseness or out-of-roundness. Replace all stripped fasteners and distorted springs.

Check idle mixture screws and float needle and seat. Replace if grooved or worn. Test float for leakage. Check float arm-to-needle surface for roughness or grooving.

Discard all old parts that will be replaced by those in the repair kit.

Gasket kits for both partial and complete overhaul are available. The selection will generally depend on the amount and kind of service to which the carburetor has been subjected.

An exploded view of a typical two-barrel carburetor employing an electrically operated mixture control is pictured in Fig. 21-43.

CARBURETOR ASSEMBLY

ASSEMBLE CARBURETOR IN A CLEAN AREA USING CLEAN TOOLS. ALWAYS USE NEW GASKETS. DO NOT USE GASKET CEMENT UNLESS DIRECTED TO DO SO BY MANUFACTURER'S INSTRUCTIONS. Assemble carefully and avoid the use of force. Use tools designed for the job, Fig. 21-44.

Tighten all fasteners securely. If torque specifications are given, use them. Perform all required adjustment checks.

CARBURETOR INSTALLATION

Clean mounting area on intake manifold. Use new mounting gaskets. Use heat baffle spacers when required. Torque fasteners.

Fill fuel bowl. Attach fuel lines, vacuum line, choke hot air line, and throttle linkage. Replace air cleaner.

Start engine. Check for leaks, choke action, and idle speed. Perform all required adjustments. Road test for performance.

THROTTLE LINKAGE ADJUSTMENT

On vehicles with automatic transmission/transaxles, adjustment of the throttle linkage must be exact. Transmission shift points, kickdown control, etc., can be affected if the linkage is improperly adjusted.

Check to make certain that the throttle plate (valve) is fully open when the accelerator is pushed against its full travel stop.

Check the linkage (cable or rod) for possible binding, kinking, or interference. If recommended, lubricate all joints and make sure that all clips, cotter pins, and springs are fastened properly. NEVER oil the carburetor throttle shaft, automatic choke, or choke shaft. Oil will collect dust and cause sticking. Fig. 21-45 illustrates a throttle cable assembly.

CHECK MANIFOLD HEAT CONTROL VALVE

The manifold heat control valve, sometimes referred to as the heat riser, will often stick due to an accumulation of carbon and lead salts.

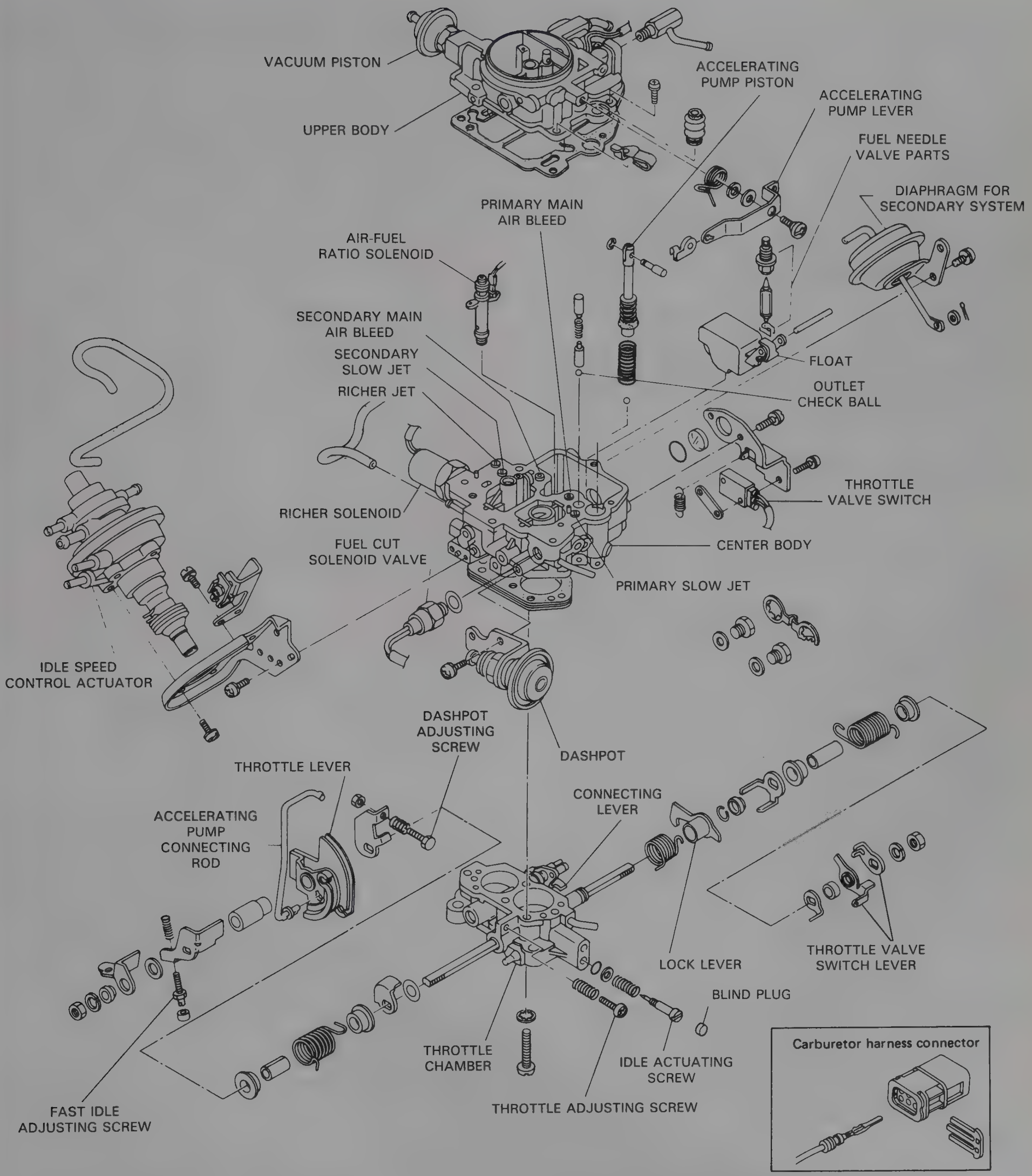

VACUUM PISTON
UPPER BODY
ACCELERATING PUMP PISTON
ACCELERATING PUMP LEVER
FUEL NEEDLE VALVE PARTS
DIAPHRAGM FOR SECONDARY SYSTEM
PRIMARY MAIN AIR BLEED
AIR-FUEL RATIO SOLENOID
SECONDARY MAIN AIR BLEED
SECONDARY SLOW JET
RICHER JET
FLOAT
OUTLET CHECK BALL
THROTTLE VALVE SWITCH
RICHER SOLENOID
FUEL CUT SOLENOID VALVE
CENTER BODY
PRIMARY SLOW JET
IDLE SPEED CONTROL ACTUATOR
DASHPOT ADJUSTING SCREW
DASHPOT
THROTTLE LEVER
CONNECTING LEVER
ACCELERATING PUMP CONNECTING ROD
LOCK LEVER
THROTTLE VALVE SWITCH LEVER
BLIND PLUG
THROTTLE CHAMBER
IDLE ACTUATING SCREW
THROTTLE ADJUSTING SCREW
FAST IDLE ADJUSTING SCREW
Carburetor harness connector

Fig. 21-43. Exploded view of a two-barrel carburetor. Study all the parts and note their relationship to the overall assembly. (Nissan)

When stuck in the OPEN position, slow warmup, carburetor icing and stalling, flat spots during acceleration, and crankcase dilution may occur. If stuck CLOSED, overheating, detonation, burned valves, and warped manifold may result.

It is important to have the heat valve free in its

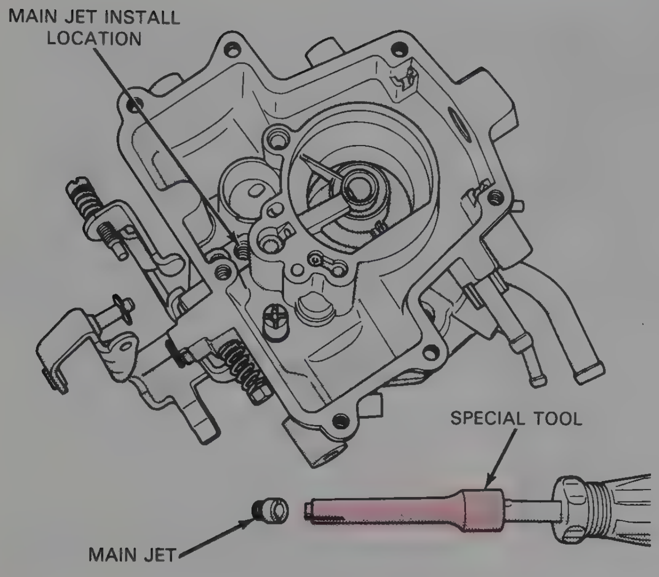

MAIN JET INSTALL LOCATION
SPECIAL TOOL
MAIN JET

Fig. 21-44. Special tools, such as this jet wrench, will greatly assist in carburetor repair and will prevent part damage. (Chrysler)

bushings. The thermostatic spring should not be distorted.

With the engine idling, accelerate quickly while watching the heat valve. The counterweight should move, indicating that the shaft is free. Hand test to make sure the valve has full travel.

If the valve is stuck, apply several drops (manifold cold) of carburetor cleaner, or some other carbon cleaning penetrant, to both ends of the shaft where it passes through the manifold. Work the valve back and forth until free. Add more cleaner as needed. When the valve is stuck so tight it cannot be moved by hand, tap the ends of the shaft after applying penetrant.

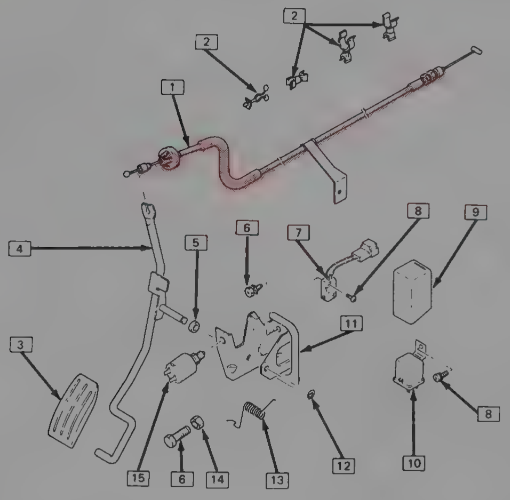

2
2
2
1
4
5
6
7
8
9
11
3
8
15
6
14
13
12
10

Fig. 21-45. Exploded view of one type of throttle linkage setup. Note the kickdown switch (15) used for automatic transmission/transaxle equipped cars. 1—Throttle cable. 2—Clip. 3—Pad. 4—Pedal. 5—Spacer. 6—Bolt. 7—Switch (manual transmission). 8—Screw. 9—Automatic choke relay cover. 10—Automatic choke relay. 11—Bracket. 12—E-clip. 13—Spring. 14—Nut. 15—Kickdown switch (automatic transmission). (Geo)

Either lubricate with a special heat resistant graphite mixture or leave dry and clean. Never use engine oil as it will burn and form more carbon.

A vacuum operated heat control valve is shown in Fig. 21-46. Do not use carburetor cleaner or oil in or on the vacuum motor assembly.

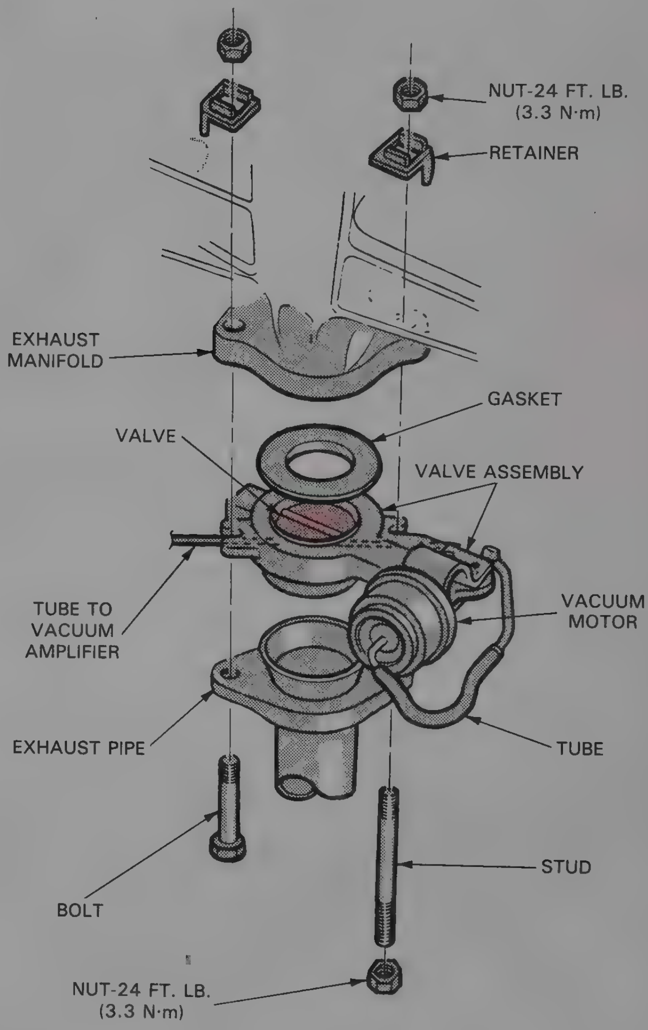

NUT-24 FT. LB. (3.3 N·m)
RETAINER
EXHAUST MANIFOLD
GASKET
VALVE
VALVE ASSEMBLY
TUBE TO VACUUM AMPLIFIER
VACUUM MOTOR
EXHAUST PIPE
TUBE
STUD
BOLT
NUT-24 FT. LB. (3.3 N·m)

Fig. 21-46. This exhaust manifold heat control valve is vacuum operated. (Chrysler)

INTAKE MANIFOLD MUST BE AIRTIGHT

When an intake manifold leak is suspected, torque the manifold fasteners. Check for a leak by squirting oil along the gasket edge. If a leak exists, the idle speed and vacuum readings will change. See Fig. 21-47.

WARNING! Use extreme caution when the engine is operating. Do not stand directly in line with the fan. Do not place your hands near the pulleys, belts, or fan. Do not wear loose clothing.

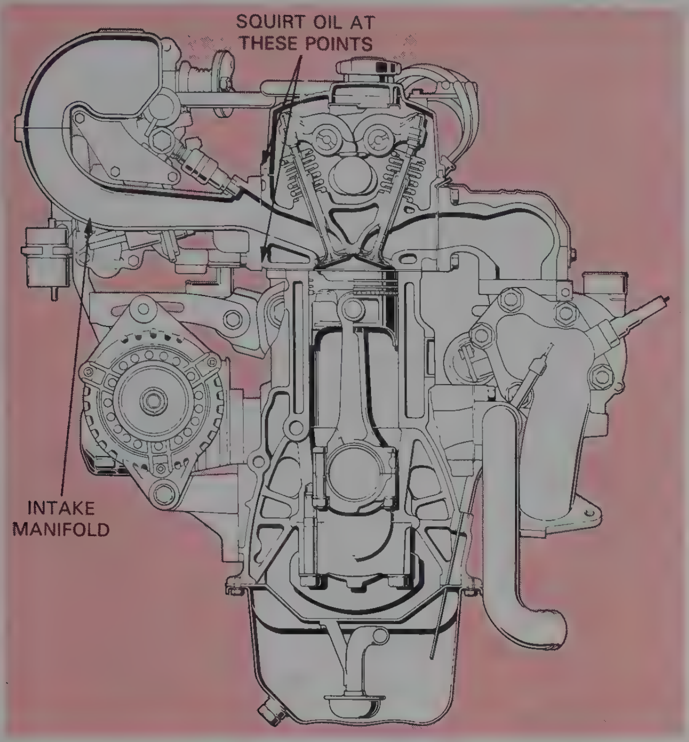


Fig. 21-47. Check the intake manifold gasket for air leaks by squirting a small amount of oil along the gasket edges. (Ford)

SUMMARY

Before diagnosing a carburetor as faulty, check other items such as ignition, wiring, etc.

Basic idle speed adjustments are the fast idle and slow idle settings. Use a tachometer to set speeds as recommended. Idle mixture setting is very important to smooth operation and exhaust emission levels. Set carefully. Replace idle screw limiter devices and test for emission level conformance.

Chokes are usually fully electric, hot air operated, or a combination of both. Some chokes have covers that are held on with rivets, while some use screws. Check choke for proper operation. If service is required, disassemble, clean, assemble, and carefully set. Check operation of choke break.

Set anti-stall dashpot and idle speedup devices to proper specifications. Check operation.

Accelerator pumps use either a piston or a diaphragm to furnish extra fuel for acceleration. Check for proper operation. Set as specified.

Float level is important to proper carburetor operation. Floats may be checked for float drop and float level. Use proper gauge if required, or as in some cases, an accurate rule. These are referred to as "dry" settings.

Fuel level in the bowl is a function of float level. "Wet" fuel level may be checked on some carburetors that list a wet (measuring actual fuel level in bowl) setting. Wet settings can be taken through a glass inspection port where provided. Some use a removable plug situated at desired level. Others require removal of the air horn cover to provide bowl access. Some allow bowl access through vent stacks or a removable cover. Be careful of fire when checking wet level.

There are many different carburetor adjustments depending upon the model. Always use a good service manual that deals with the exact carburetor you are working on.

Scribe vital parts before disassembly to aid in proper reassembly.

Wash all metallic parts in proper solvent. Rinse and blow dry. Many parts cannot be washed.

Inspect all parts for wear, breakage, and binding. Replace defective units.

If a repair kit is being used, make certain it is correct.

Assemble carburetor carefully. Work with clean parts, in a clean area with clean tools. Check and adjust all settings as specified.

Install carburetor using proper gaskets and insulators. Torque fasteners. Secure lines and hoses. Start engine and check performance.

Throttle linkage must be adjusted properly and manifold heat valve free and functioning. Check intake manifold, vacuum lines, and fuel lines for leakage.

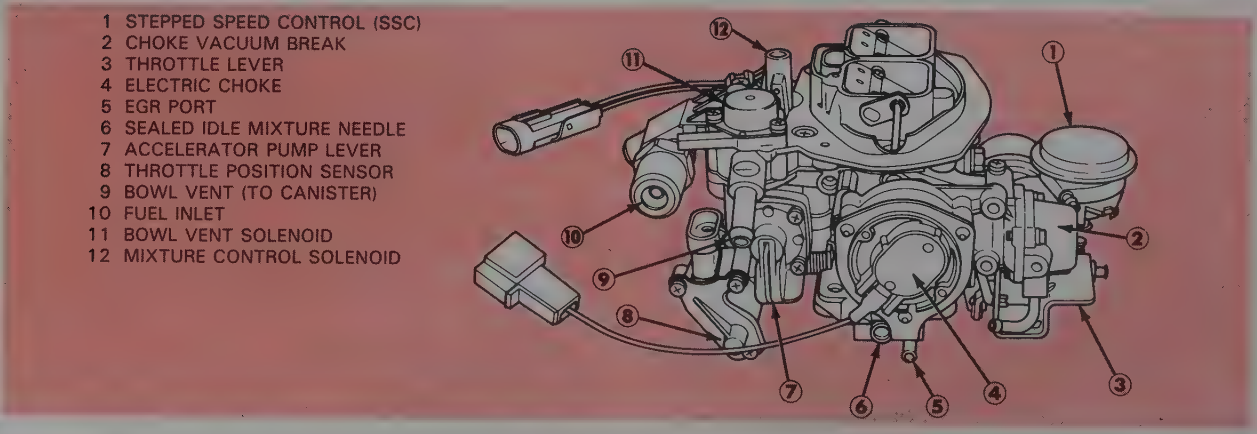
KNOW THESE TERMS

Fast idle, Hot idle, Slow idle, Idle mixture, Idle screw, Manual choke, Automatic choke, Thermostatic spring, Choke "break," Anti-stall dashpot, Accelerator pump, Fuel bowl, Bowl vent, Float drop, Float level, Fuel level, Fuel level "wet" setting, "Dry" setting, Heat control valve, Variable venturi, Remote choke, Choke stove, Aneroid, Altitude compensation.

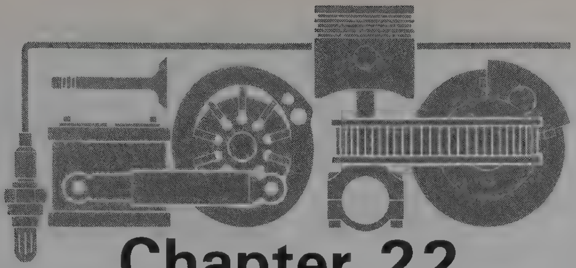
QUIZ - Chapter 21

1. Before condemning the carburetor when having fuel system difficulty, name three other things that should be checked!
2. Fast idle adjustments are performed with a cold engine. True or False?
3. Slow idle speed is generally around 1,000 rpm. True or False?
4. Slow idle adjustments must be made before the choke is completely open. True or False?
5. When setting slow idle, the hot idle compensator valve must be:
   a. Held open.
   b. Removed.
   c. Held shut.
   d. Alternately opened and closed.

6. When adjusting the idle speed with an idle air screw:
   a. Open the screw all the way.
   b. Use as little air as possible.
   c. Use as much air as possible.
   d. Close screw all the way.
7. The idle mixture screw:
   a. Opens or closes the throttle.
   b. Determines amount of fuel-air mixture that reaches cylinder during idling.
   c. Governs the choke valve tension.
   d. Must contact the fast idle cam.
8. A vacuum gauge is a handy tool for setting the idle mixture. True or False?
9. Always seat idle mixture screws very firmly against their seats and then back off about 1-1/4 turn. True or False?
10. Adjusting the idle mixture can change the idle rpm. True or False?
11. The idle speed and the __________ __________ should be adjusted one after the other until both are correct.
12. Where should the choke knob be in relation to the dash when the manual choke valve is fully open?
13. The automatic choke is adjusted by altering the tension on the ______________ ______________.
14. When the engine is cold, the automatic choke valve should be ________________.
15. Choke vacuum "break" means:
   a. Partial opening of choke valve by a piston or diaphragm when engine is started.
   b. Full closing of choke by vacuum means.
   c. That when choke opens a certain distance, vacuum in air horn is broken.
   d. Using vacuum to slow down opening of choke.
16. The choke "unloader" or throttle "break" forces the choke partially open when the throttle is moved to the wide open position. True or False?
17. The anti-stall dashpot automatically adjusts itself. True or False?
18. Describe how to perform a quick check on the accelerator pump.
19. The initial float level "dry" setting is often followed (carburetor installed) by a measurement to determine the actual fuel "wet" level in the bowl. True or False?
20. Fuel level in the bowl is best adjusted by:
   a. Adjusting the fuel pump pressure.
   b. Changing the bowl fuel inlet needle.
   c. Altering the main jet size.
   d. Bending the float needle contact arm.
21. ____________ carburetor parts before disassembly to assist in correct reassembly.
22. The best method to use for cleaning carburetor jets is to:
   a. Run a drill through the jet.
   b. Run a soft wire through the jet.
   c. Blow out with an air blast.
   d. Run a wire through and then blow out.
23. Always oil all carburetor moving parts. True or False?
24. Name two substances that cause the exhaust heat control valve to stick.
25. Use engine oil to lubricate the exhaust heat control valve. True or False?
26. Intake manifold air leaks can often be found by squirting ____________ along the gasket edge.
27. Automatic chokes can be either:
   a. Hot air operated.
   b. Electrically operated.
   c. Hot air with electric assist operated.
   d. All of the above.
   e. None of the above.
28. Explain why limiter caps are used and why it is important that they be replaced following service.
29. The altitude compensating air valve is actuated by an ______________ capsule.
30. When cleaning, always direct a blast of air inside any vacuum operated diaphragm devices to make certain all oil is removed. True or False?
31. List four carburetor parts that should NOT be soaked in carburetor cleaner.


1 STEPPED SPEED CONTROL (SSC)
2 CHOKE VACUUM BREAK
3 THROTTLE LEVER
4 ELECTRIC CHOKE
5 EGR PORT
6 SEALED IDLE MIXTURE NEEDLE
7 ACCELERATOR PUMP LEVER
8 THROTTLE POSITION SENSOR
9 BOWL VENT (TO CANISTER)
10 FUEL INLET
11 BOWL VENT SOLENOID
12 MIXTURE CONTROL SOLENOID
⑫
⑪
①
⑩
②
⑨
⑧
⑦
⑥
⑤
④
③

Modern two-barrel carburetor. Study the various parts and their locations. (GM)



Chapter 22

FUEL SYSTEM SERVICE — FUEL INJECTION

After studying this chapter, you will be able to:
- ☐ Explain mechanical fuel injection construction, operation, and service.
- ☐ Describe the construction, operation, and service of intermittent and continuous electronic fuel injection.
- ☐ Explain diesel injection construction, operation, and service.
- ☐ Describe the construction, operation, and service of turbochargers.
- ☐ Service different types of air cleaners.
- ☐ Perform a fuel mileage test.

WARNING!

REMEMBER THAT THE FUEL LINES IN A FUEL INJECTION SYSTEM MAY BE UNDER PRESSURE. BEFORE WORKING ON FUEL LINES OR REMOVING ANY PART OF THE SYSTEM, ALWAYS DISCONNECT THE BATTERY GROUND STRAP. ALSO, CAREFULLY BLEED OFF LINE PRESSURE BY OPENING A FITTING A SMALL AMOUNT OR BY OPENING A PRESSURE BLEEDER VALVE (SCHRADER) WHERE USED. COVER FITTING OR BLEEDER WITH A CLOTH TO CATCH ANY FUEL THAT MAY SPEW OUT. DISPOSE OF FUEL-SOAKED CLOTH PROPERLY. BE CAREFUL OF FIRE!

FUEL INJECTION

Although fuel injection has been used on and off for a number of years, the current thrust in emission control and fuel conservation has sparked renewed interest. Most cars and trucks are now being offered with fuel injection systems. Advances in electronic technology have permitted the development of very sophisticated and effective systems.

WHY FUEL INJECTION?

A carburetor mixes fuel and air in proportions somewhat near what is needed. There are many operating conditions, however, in which the carburetor cannot supply the ideal mixture. Since operating conditions change very rapidly, the typical carburetor cannot meet the varying demands.

Fuel injection, on the other hand, can administer a much more closely controlled mixture. While this mixture is not always ideal, it more closely approximates what is required. This permits better gas mileage, smoother operation, more power, and lowered exhaust emission levels.

WHAT IS FUEL INJECTION?

Fuel injection is a system in which a measured quantity of fuel is forcibly sprayed (injected) into the cylinder (as with diesel injection). Or, the fuel is injected into the valve port itself or into the intake manifold close to the port area (as with gasoline engines). This charge of atomized fuel then mixes with the air moving into the cylinder resulting in a specific mixture filling the cylinder. Fig. 22-1 shows how one

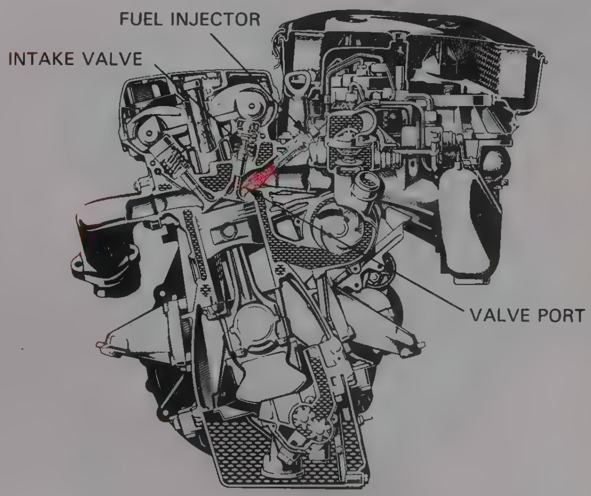


Fig. 22-1. Gasoline engine incorporating fuel injection. The fuel injector is spraying fuel into the intake valve port area. It is then drawn into the cylinder with air during the intake stroke. (Mercedes-Benz)

system injects fuel into the intake valve port area. Note that the fuel is directed at the base of the intake valve head.

TWO BASIC SYSTEM DESIGNS

Although there are numerous gasoline fuel injection system designs, most systems in use today can be broken down into TWO basic types—MECHANICAL and ELECTRONIC.

MECHANICAL FUEL INJECTION

The mechanical fuel injection system uses an engine driven injection pump. An electric fuel pump forces gasoline from the tank through fine filters and on to the injection pump. The injection pump, through a series of pistons and cams, compresses a measured quantity of gasoline and delivers it to a specific injector. The fuel charge, under pressure from the pump, pushes the spring-loaded injector needle off its seat. Fuel is forced through the injector nozzle. As the fuel speeds through the nozzle, it is broken (atomized) into mist-like droplets that readily mix with the incoming airstream. See Fig. 22-1.

The injection pump meters the amount of fuel needed in accordance with throttle valve positioning. To meet varying conditions, such as cold starting or high altitude operation, the positioning of the injection pump control rod is automatically altered to compensate for the immediate fuel demand.

A typical mechanical fuel injection system is shown in Fig. 22-2. This system uses a four-piston pump. Injection valves open at around 450 psi (3100 kPa). The fuel charge is injected into the valve port area against the base of the intake valve head. Injection is timed to occur during the initial phase of the intake stroke.

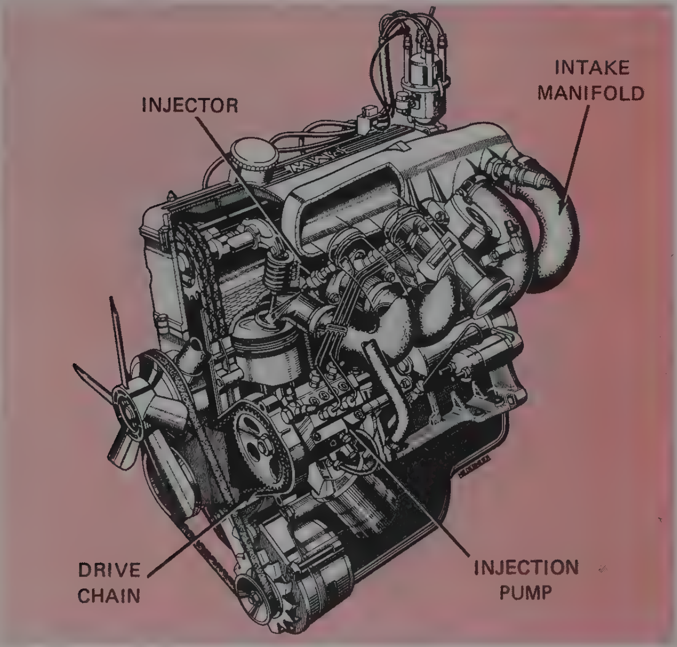


Fig. 22-2. Mechanical fuel injection system. Each cylinder, at exact time needed, has a metered amount of fuel injected into intake port area. (BMW)

MECHANICAL FUEL INJECTION SERVICE

Mechanical fuel injection systems require PRECISE adjustments. Use proper service tools and test instruments. A manufacturer's repair manual covering the EXACT system at hand must be used. Follow instructions and recommended clearances, adjustments, and pressures!

Some of the more common service adjustments, inspections, and repairs follow.

FUEL LINE SERVICE

Check condition of all hose and tubing. Look for any signs of fuel leakage. Check fittings and clamps for tightness. Observe routing of hose, watching for abrasion, too near heat, etc. Replace any parts deemed defective. Use proper replacement parts of the correct size and material. After repair, test for leaks.

FILTER SERVICE

Fuel cleanliness is critical on mechanical injection systems. Injector pump internal parts are fitted with utmost precision and any foreign particles can cause problems. Clean and/or replace all filters as recommended.

FUEL PUMP SERVICE

Pump output, both in pressure and volume may be checked. Check electrical connections for looseness and/or corrosion. If pump seems noisy, check rubber mountings (where used) and also check for interference with other objects. Make certain all hoses are in good condition and that clamps and fittings are tight!

LINKAGE CHECKS

Linkage adjustments must be exactly as specified. Linkage should move freely without binding or interference with other parts. Lubricate as needed. When adjustment is necessary, follow maker's specifications. When needed, use recommended setting tools such as graduated disc or spacers. Use care to get all adjustments CORRECT. Fig. 22-3 shows the typical detailed linkage adjustment specifications needed for just one section of the linkage system.

IDLE ADJUSTMENT

When adjusting the engine idle, make certain the proper rpm is used and that specified emission values

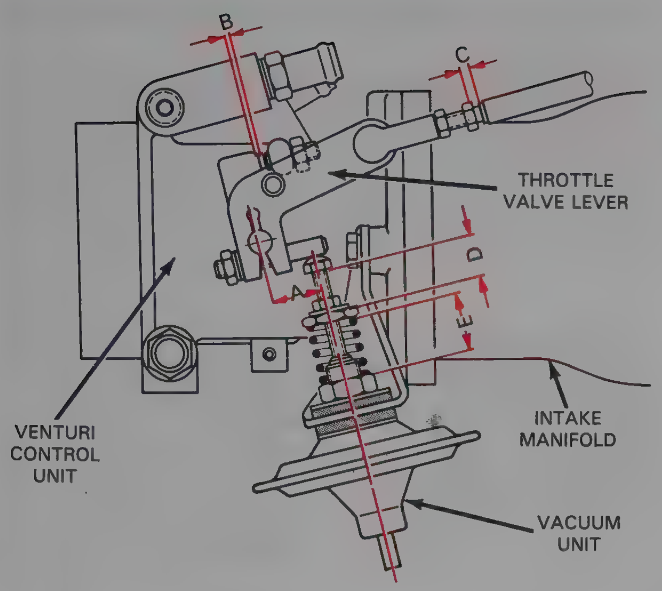


Fig. 22-3. Mechanical fuel injection linkage adjustments must be precise. Follow maker's specifications: A—Shaft distance. B—Throttle valve opening. C—Idle travel of sliding rod. D—Length of thrust bolt. E—Spring length. (Mercedes-Benz)

are met. Some systems have two idle adjusting screws—one on the injector pump and another, usually an idle speed air screw, in the intake manifold. They are used in conjunction with each other to secure the proper fuel-air mix. Fig. 22-4 shows one setup used on the injector pump.

PART AND FULL LOAD ADJUSTMENTS

Adjusting devices, such as shown in Fig. 22-4 are used to provide proper part load and full load fuel mix adjustments.

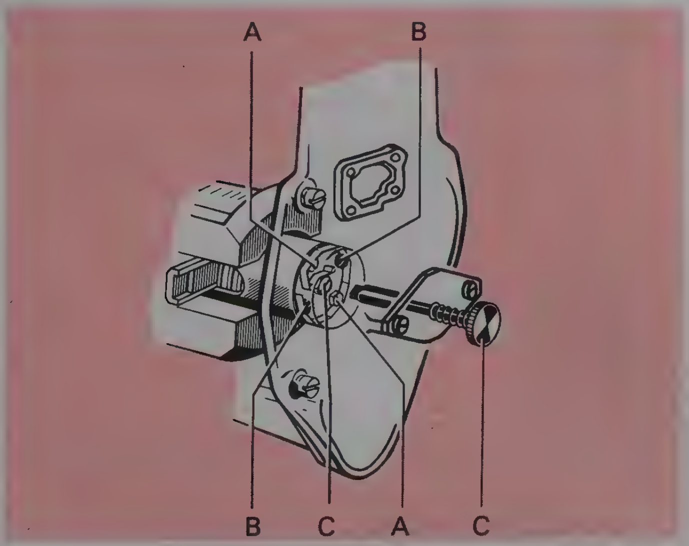


Fig. 22-4. One type of idle adjustment for a gasoline fuel injection system: A—Top part load adjusting screw. B—Bottom part load adjusting screw. C—Idle speed adjusting screw.

Such adjustments are best made on a chassis dynamometer, but if one is not available, road testing will suffice.

Follow maker's directions and make any adjustment in SMALL amounts.

INJECTOR PUMP OVERHAUL

Proper injector pump overhaul requires the use of a test stand and appropriate tools. Clearances are precise and require absolute cleanliness and care. DO NOT ATTEMPT PUMP OVERHAUL UNLESS PROPER TOOLS AND SPECIFICATIONS ARE AVAILABLE!

When removing or installing pump, pay particular attention to spacers, adjustment washers, and index marks. Torque fasteners.

INJECTOR SERVICE

The injector valves can be tested for leakage, proper opening pressure, and spray pattern shape. Use an injector test unit. Replace faulty valves. When installing injectors, use new seal rings and torque to specs.

OTHER CHECKS AND ADJUSTMENTS

Depending upon the particular injection system at hand, there can be other related control units in the system such as a starting valve, thermo-switch, etc. Check for proper operation. Adjust, repair, or replace as needed.

ELECTRONIC FUEL INJECTION

The electronic fuel injection system does not use a mechanical injection pump. It relies on an electric fuel pump to provide the needed pressure. Pressure requirements are far lower. While there are numerous electronic fuel injection systems, they can be classified under TWO basic types — INTERMITTENT injection and CONTINUOUS injection.

INTERMITTENT INJECTION SYSTEMS

In the intermittent systems, the injector valves are opened for a very brief (several milliseconds) period of time during which the fuel passes through the injector nozzle.

The fully timed intermittent system opens each injector briefly in exact time with the intake stroke for the cylinder served by the injector.

A very popular application of the intermittent system opens the injectors in groups of two or more at the same time. On a four cylinder engine, there would be two groups of two. On a V-8, there could be two groups of four each. In a two-group system, some of the injectors would discharge fuel at or near the moment of intake. The remaining injectors in each group would discharge atomized fuel into their respective intake manifold port areas where it would remain until the intake stroke. The fact that the fuel is injected for some cylinders before the intake stroke does not have a significant effect upon performance. A schematic of one type of intermittent fuel injection system is illustrated in Fig. 22-5.

Another system uses only two injectors. They discharge fuel into the throttle body area just above the throttle valves. The fuel, as needed by the cylinders, is drawn through the intake manifold much as in the case of a carbureted engine. This, too, is a very efficient system. See Fig. 22-6.

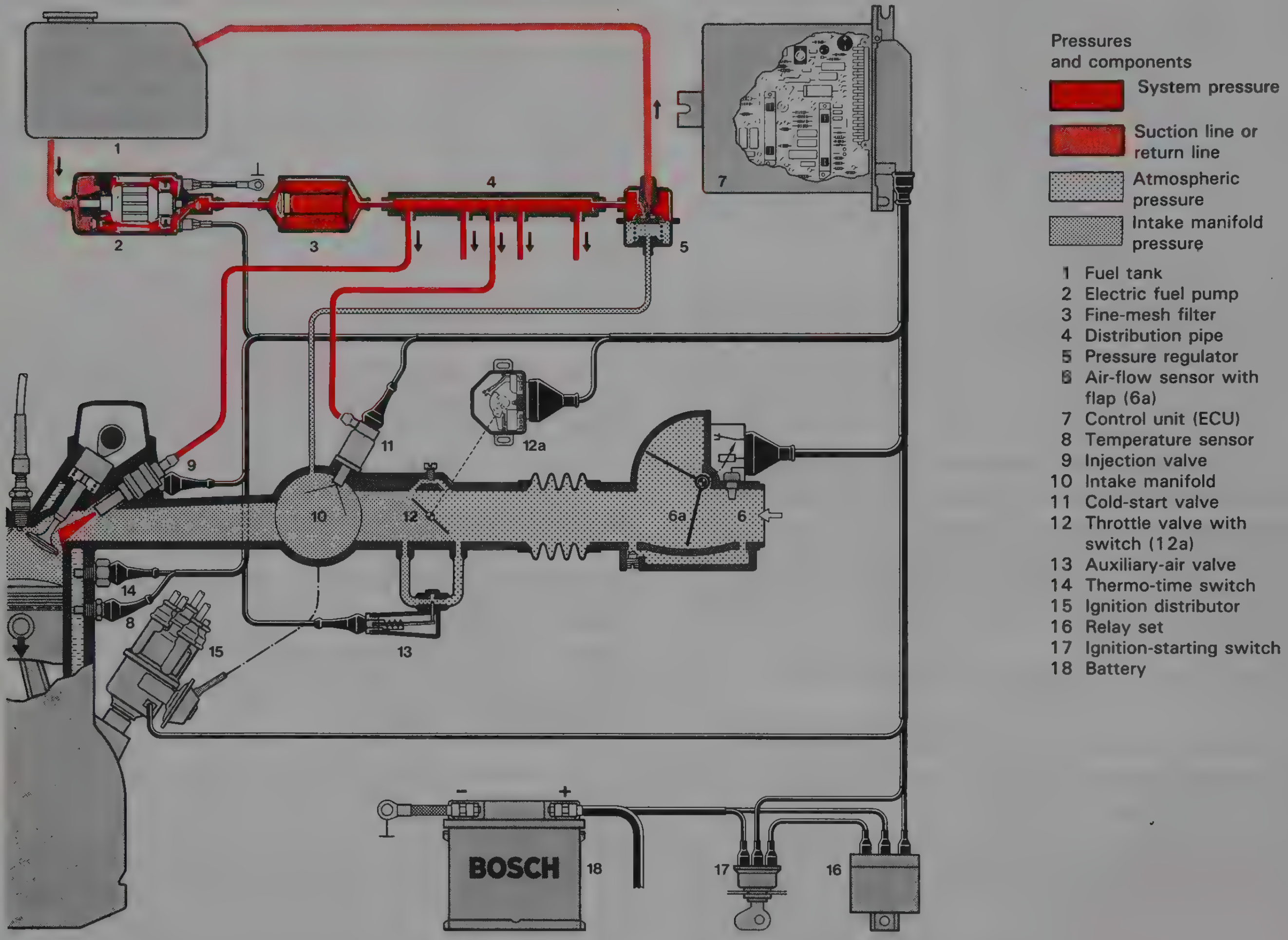

1
2
3
4
5
6
6a
7
8
9
10
11
12
12a
13
14
15
16
17
18
BOSCH
-
+
Pressures and components
System pressure
Suction line or return line
Atmospheric pressure
Intake manifold pressure
1 Fuel tank
2 Electric fuel pump
3 Fine-mesh filter
4 Distribution pipe
5 Pressure regulator
6 Air-flow sensor with flap (6a)
7 Control unit (ECU)
8 Temperature sensor
9 Injection valve
10 Intake manifold
11 Cold-start valve
12 Throttle valve with switch (12a)
13 Auxiliary-air valve
14 Thermo-time switch
15 Ignition distributor
16 Relay set
17 Ignition-starting switch
18 Battery

Fig. 22-5. Fuel flow in one type of intermittent fuel injection system. Note the various electrical parts. (Bosch)

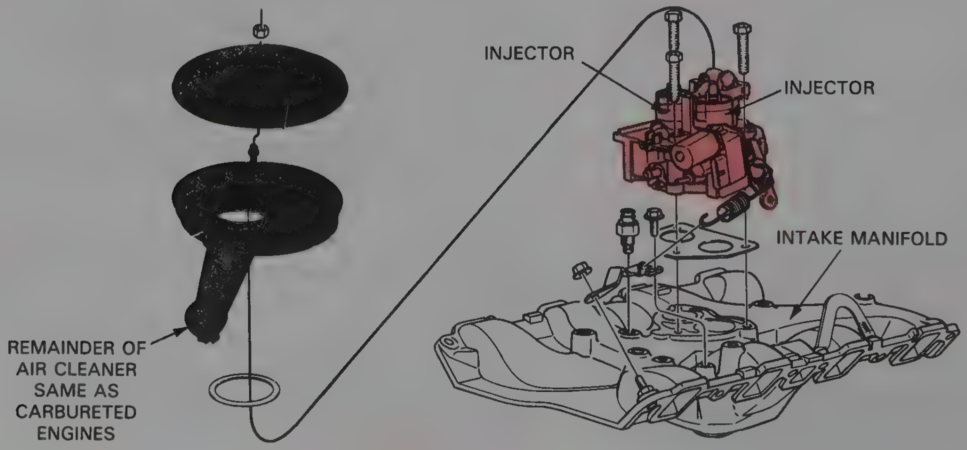

INJECTOR
INJECTOR
INTAKE MANIFOLD
REMAINDER OF AIR CLEANER SAME AS CARBURETED ENGINES

Fig. 22-6. Intake manifold and throttle body assembly. This system uses two injectors set into throttle body. Each injector feeds a separate portion of manifold. (Cadillac)

INTERMITTENT INJECTION SYSTEM OPERATION

The typical intermittent system can be broken into four basic parts:

1. Air induction system.
2. Fuel delivery system.
3. Electronic control unit.
4. Electronic sensors.

AIR INDUCTION SYSTEM

The air delivery system consists of the usual air cleaner with the hot-cold air entry control system. From the air cleaner, the air passes through a throttle body section and on into the intake manifold. Air movement is controlled by the throttle valve. A typical intake manifold and throttle body is pictured in Fig. 22-6.

FUEL DELIVERY SYSTEM

Some systems use an in-tank fuel pump that forces fuel to another pump (often chassis-mounted). The second pump forces fuel through a filter and on to the fuel injection pump. Many systems employ only a single, chassis-mounted pump.

A fuel delivery system using a single, in-tank pump is shown in Fig. 22-7. The in-tank, electric pump forces fuel from the tank, through a filter, and into the fuel rail. Depending on the design, pressure in these systems can range from 11 psi to 39 psi (76 kPa to 269 kPa). Pressure is maintained by the fuel pressure regulator. The pump shown in Fig. 22-7 is controlled by the fuel pump relay, which, in turn, is controlled by the electronic control unit (ECU).

Any fuel not used by the injectors is routed through the regulator and back to the tank.

Fig. 22-8 shows the construction of one type fuel pressure regulator. This version is incorporated into the throttle body assembly. This specific system operates at a constant 11 psi (75.8 kPa) at the injector. Study fuel flow, Fig. 22-8.

A cross-sectional view of another type pressure regulator is shown in Fig. 22-9. This setup applies vacuum from the intake manifold to one side of the diaphragm and fuel pressure to the other. The vacuum balancing helps to maintain a constant pressure drop across the injectors, Fig. 22-9.

One type of roller-vane fuel pump is pictured in Fig. 22-10. It has a pressure relief valve to vent fuel back to the tank whenever system pressure exceeds a specific amount.

A fuel rail and injector setup is shown in Fig. 22-11. The "rail" is a rigid piece of steel tubing that feeds fuel to the injectors.

INJECTOR OPERATION

One type of electronic injector is illustrated in Fig. 22-12. Note that this injector is not rigidly affixed to a fuel rail, but is connected by flexible hose.

Fuel passes from the fuel rail to the injector via the flex hose (A). Filter (B) is built into the injector. The fuel moves down through the injector until stopped at the nozzle by the sealing needle (F).

When the injector is energized by the control unit, the magnetic winding (C) forms a strong magnetic field that attracts the sealing needle armature (E) and draws

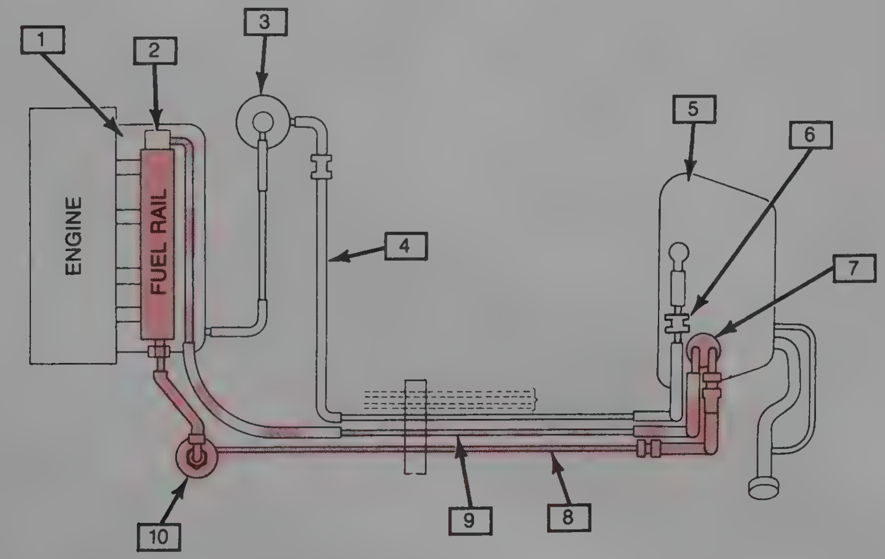


Fig. 22-7. Electronic fuel injection fuel delivery system. 1—Common chamber. 2—Fuel pressure regulator. 3—Vapor canister. 4—Canister pipe. 5—Fuel tank. 6—Rollover check valve. 7—Fuel pump. 8—Fuel feed line. 9—Excess fuel return line. 10—Fuel filter. (Geo)

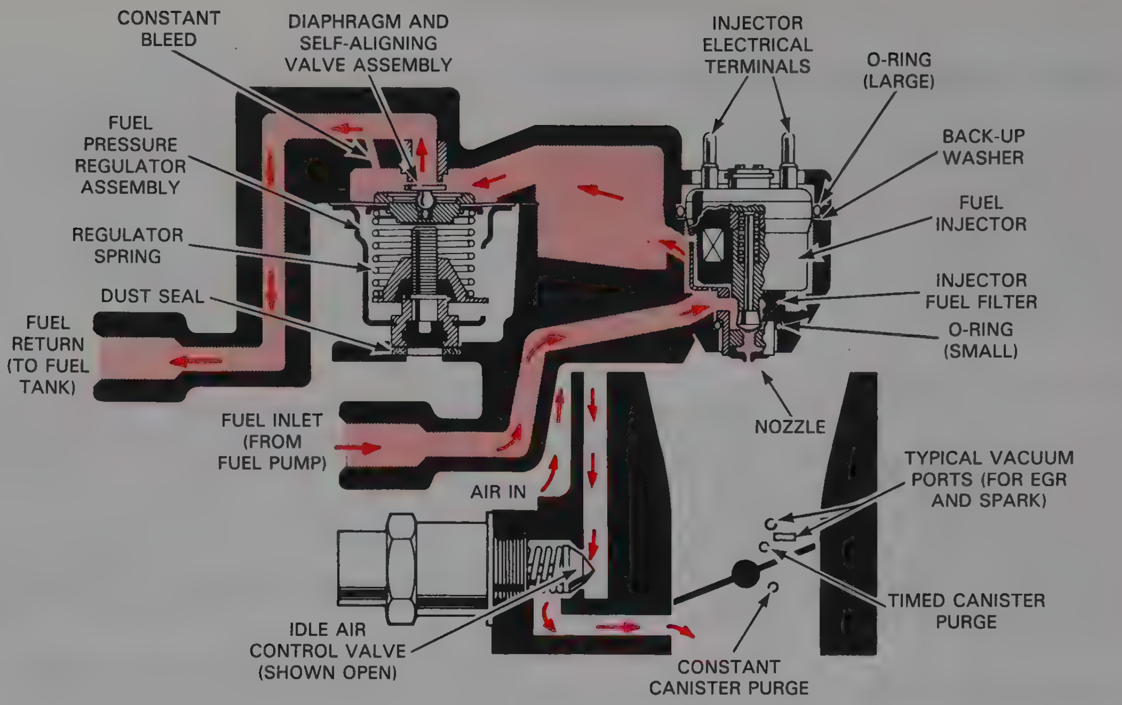

CONSTANT BLEED
DIAPHRAGM AND SELF-ALIGNING VALVE ASSEMBLY
INJECTOR ELECTRICAL TERMINALS
O-RING (LARGE)
BACK-UP WASHER
FUEL PRESSURE REGULATOR ASSEMBLY
FUEL INJECTOR
REGULATOR SPRING
INJECTOR FUEL FILTER
DUST SEAL
O-RING (SMALL)
FUEL RETURN (TO FUEL TANK)
NOZZLE
FUEL INLET (FROM FUEL PUMP)
TYPICAL VACUUM PORTS (FOR EGR AND SPARK)
AIR IN
TIMED CANISTER PURGE
IDLE AIR CONTROL VALVE (SHOWN OPEN)
CONSTANT CANISTER PURGE

Fig. 22-8. One form of fuel pressure regulator. This one maintains a constant 11 psi pressure. (Buick)

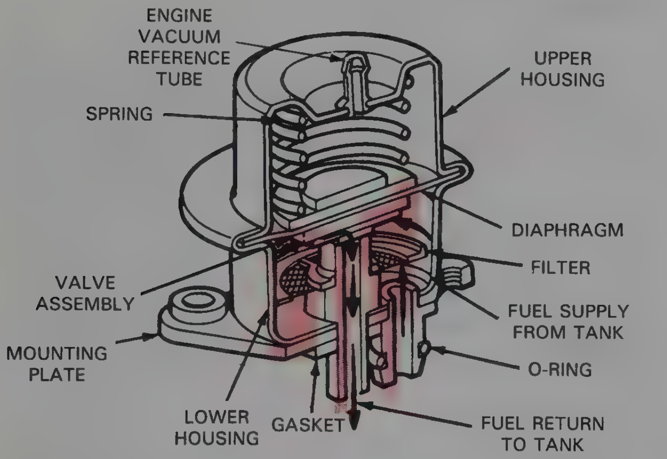

ENGINE VACUUM REFERENCE TUBE
UPPER HOUSING
SPRING
DIAPHRAGM
FILTER
VALVE ASSEMBLY
FUEL SUPPLY FROM TANK
MOUNTING PLATE
O-RING
LOWER HOUSING
GASKET
FUEL RETURN TO TANK

Fig. 22-9. Another type of fuel pressure regulator. Vacuum working on diaphragm helps maintain constant pressure drop across injectors. (Ford)

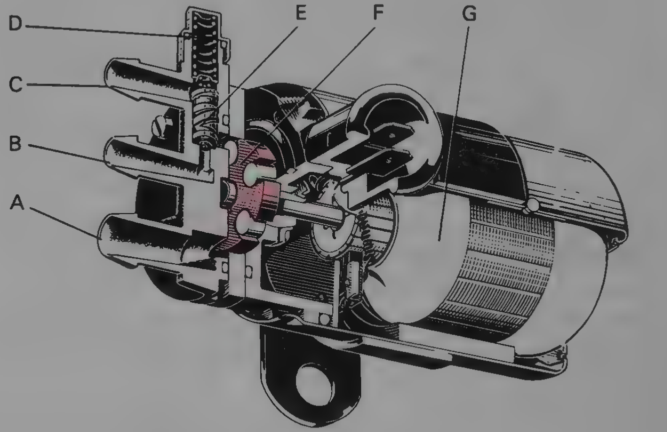


Fig. 22-10. Roller-vane electric fuel pump. A—Fuel inlet. B—Fuel outlet. C—Relief valve fuel outlet. D—Relief valve spring. E—Relief valve plunger. F—Roller-vane assembly. G—Armature. (Volvo)

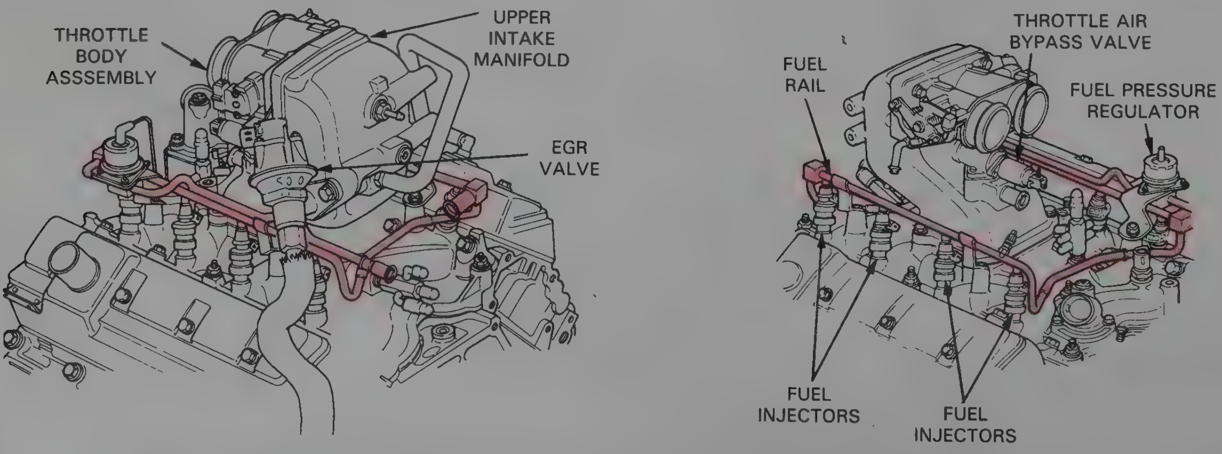

THROTTLE BODY ASSSEMBLY
UPPER INTAKE MANIFOLD
EGR VALVE
THROTTLE AIR BYPASS VALVE
FUEL RAIL
FUEL PRESSURE REGULATOR
FUEL INJECTORS
FUEL INJECTORS

Fig. 22-11. Fuel rail as used on one fuel delivery system. Note how injectors are connected directly to the fuel rail. Others are attached using a flexible hose. (Ford)

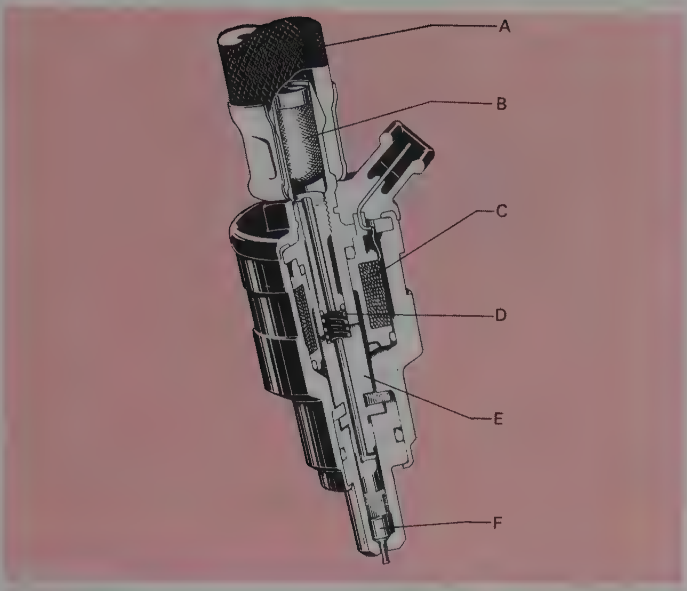


Fig. 22-12. Electrically operated fuel injector. A—Flex hose. B—Filter. C—Winding. D—Needle return spring. E—Needle armature. F—Sealing needle. (Volvo)

it upward against spring pressure (D). In this injector, the sealing needle (F) is lifted about .006 in. (0.15 mm), allowing fuel to spray out. When de-energized, spring pressure forces the needle closed. Spray interval, often called "pulse width" (length of time injector remains open), varies from 2 to 10 milliseconds for this particular unit.

INJECTION TIMING

There are two types of injection timing: SYNCHRONOUS AND ASYNCHRONOUS. Synchronous injection is coordinated with the engine speed (crankshaft position) sensor signal. Asynchronous injection occurs independently of the engine speed sensor signal.

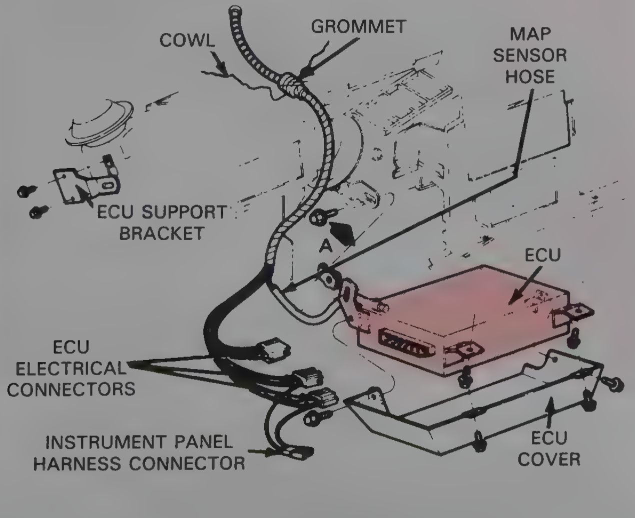

COWL
GROMMET
MAP SENSOR HOSE
ECU SUPPORT BRACKET
A
ECU
ECU ELECTRICAL CONNECTORS
INSTRUMENT PANEL HARNESS CONNECTOR
ECU COVER

Fig. 22-13. Electronic control unit (ECU) is connected by means of a wiring harness plug-in. (Cadillac)

ELECTRONIC CONTROL UNIT

The electronic control, Fig. 22-13, is in the form of a preprogrammed computer. Size and complexity varies depending upon the system. It usually is located in a protected area away from excessive heat. The control unit is connected to the system by means of a wiring harness plug.

The electronic control unit constantly receives signals from a number of sensors. From this input, the control unit evaluates engine fuel needs and adjusts injector pulse width accordingly. The control also energizes the fuel pumps. Fig. 22-14 illustrates one type of electronic control. Note the large number of electronic units.

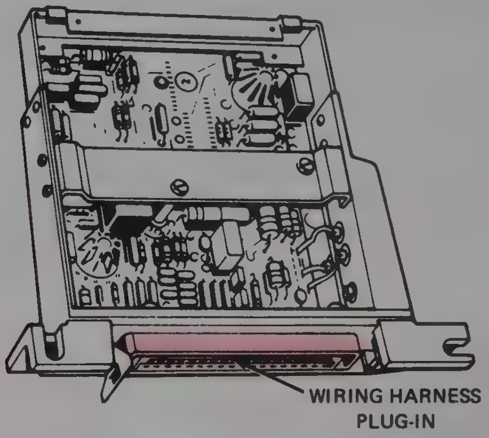

WIRING HARNESS PLUG-IN

Fig. 22-14. One type of electronic control unit. These are precision units not usually serviced in the field (shop) but exchanged for a good unit. (Opel)

ELECTRONIC SENSORS

The electronic sensors monitor (check) various engine functions and feed this information to the electronic control unit. The number and types of sensors vary with the system. Fig. 22-15 illustrates some of the sensors

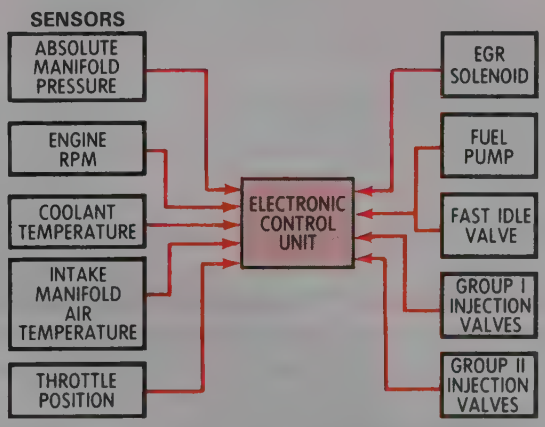

SENSORS
ABSOLUTE MANIFOLD PRESSURE
ENGINE RPM
COOLANT TEMPERATURE
INTAKE MANIFOLD AIR TEMPERATURE
THROTTLE POSITION
ELECTRONIC CONTROL UNIT
EGR SOLENOID
FUEL PUMP
FAST IDLE VALVE
GROUP I INJECTION VALVES
GROUP II INJECTION VALVES

Fig. 22-15. Diagram showing "sensors" that feed information into computer (electronic control unit). (Cadillac)

used by one system. Note that information from the sensors enters the control unit (computer) where it is processed into commands for the various control units such as the EGR solenoid, fuel pump, fast idle valve, and injection valves.

SPEED SENSOR (ENGINE RPM)

The engine speed sensor monitors engine rpm. One type of speed sensor is pictured in Fig. 22-16. The triggering contacts (A) are actuated by a cam on the distributor shaft. The unit is connected to the control unit via a wiring harness plug-in (B). The speed sensor information is utilized by the control unit (along with other sensor input) to help determine injector pulse timing and pulse width (length of time injector is open).

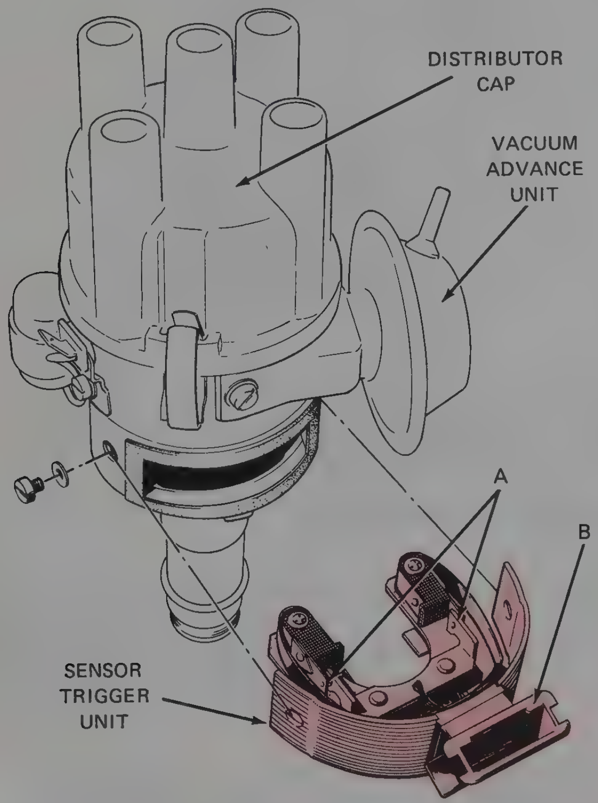


Fig. 22-16. A speed sensor assembly. Unit is triggered by the distributor shaft. A—Trigger contacts. B—Wiring plug-in connector. (Volvo)

THROTTLE POSITION SENSOR

Throttle position is relayed to the control unit by the throttle position sensor. It is connected via a harness plug-in. A throttle position sensor for one system is shown in Fig. 22-17.

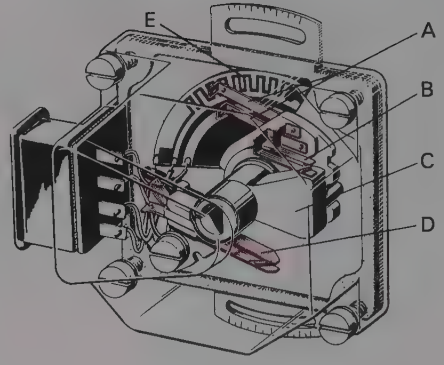


Fig. 22-17. Throttle position sensor. A—Slip switches. B—Switch for accelerator function. C—Connects to throttle valve shaft. D—Switch for co-potentiometer. E—Zigzag.

As the engine is accelerated, the switch contacts (B) are joined. Current flows from one switch to the other. When the slip contacts (A) slide over the zigzag (E), impulses (their rapidity and number) are transmitted to the control unit. Injector pulse width is then altered to meet demand.

During deceleration, switch (D) is closed. If engine speed exceeds 1,700 rpm, the control stops fuel injection until rpm reaches 1,000. Below 1,000 rpm, injector flow is resumed. If, for any reason, the accelerator is depressed while the rpm range is between 1,700 and 1,000, switch (D) is reopened and injection immediately resumes.

MANIFOLD PRESSURE SENSOR

Engine loading (how hard engine is pulling) is transmitted to the control unit by means of an intake manifold pressure sensor.

The sensor shown in Fig. 22-18 converts manifold

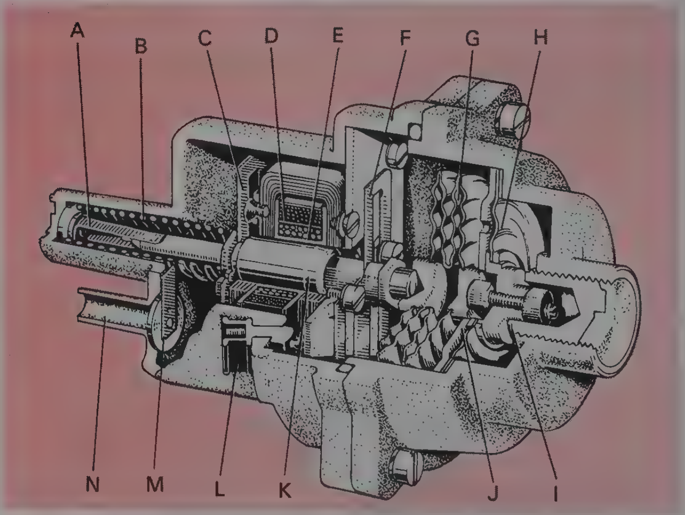


Fig. 22-18. Pressure sensor. A—Damping spring. B—Coil spring. C—Leaf (suspension) spring. D—Armature secondary winding. E—Armature primary winding. F—Suspension spring. G—Bellows. H—Diaphragm. I—Full load stop. J—Part load stop. K—Armature. L—Electrical plug-in connector. M—Valve. N—Hose connection. (Volvo)

pressure into an electronic signal by means of a sliding armature (K) moving inside transformer coil (D). The armature is balanced by spring pressure (B) forcing the armature to the right. Atmospheric pressure exists on the right side of diaphragm (H), while manifold pressure (varying partial vacuum) exists on the left side. Evacuated bellows (G) expand as manifold vacuum decreases, which alters armature position in addition to armature movement caused by diaphragm (H) movement. As manifold vacuum increases, the armature is forced to the left against spring pressure. The armature movement, in either direction, alters transformer reluctance which in turn, alters the control signal.

TEMPERATURE SENSOR

The intermittent injection system generally will have two temperature sensors — one for the engine coolant and the other to monitor intake air temperature.

OTHER INJECTION SYSTEM UNITS

In addition to the sensors described, the system can incorporate other units for special functions. Among these are the COLD START VALVE, THERMAL TIMER, and the AUXILIARY AIR REGULATOR.

COLD START VALVE

When starting a cold engine, it is imperative that the mixture be somewhat enriched (adding of fuel to intake airstream). The cold start valve, Fig. 22-19, accomplishes this by injecting extra fuel into the intake manifold for a temperature controlled period of time.

When the cold engine is cranked, current from the starter is fed to the cold start injector magnetic winding (A) in Fig. 22-19. From the cold start windings, current will flow to the thermal time switch and on to ground.

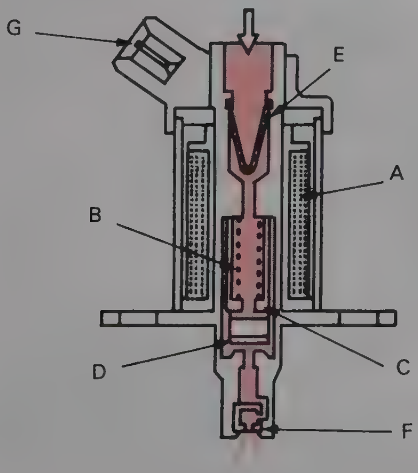


Fig. 22-19. One type of cold start valve (injector). A—Solenoid winding. B—Return spring. C—Electromagnet armature (valve). D—Seal. E—Fuel inlet filter. F—Nozzle. G—Electrical connection. (Bosch)

Current will flow for a maximum of 12 seconds when engine temperature is below −5°F (−21°C). At temperatures exceeding this level, the amount of time current is passed to the winding will gradually decrease until an engine temperature of 95°F (35°C) is reached. Above this point, the cold start will not be actuated. NOTE: Regardless of temperature, current flow will stop when the starter switch is released.

Current passing through the winding will form a magnetic field and draw the armature (C) up, which allows seal (D) to be drawn off of its seat. The fuel will flow through the unit and spray out at the injector nozzle (F). See Fig. 22-19.

THERMAL TIME SWITCH

To prevent prolonged actuation of the cold start valve, as well as use at temperatures above a certain degree, a thermal time switch is used, Fig. 22-20. The switch screws into the engine water jacket. When coolant temperature falls below a set point, 95°F (35°C) for this time switch, the contact points (A) are closed.

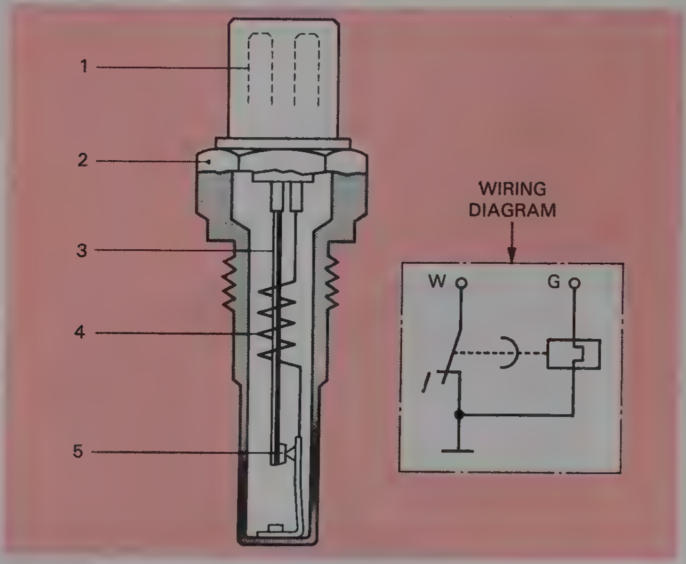


Fig. 22-20. Thermal time switch limits length of time cold start valve can operate. 1—Electrical terminal. 2—Threaded pin. 3—Bimetal. 4—Heating filament. 5—Switching contact. (Bosch)

Current will flow from the cold start injector through wire (D) to ground through the points (A) and the cold start injector will function.

As long as the starter is operated, current will flow through wire (C) to ground through the bimetallic spring (B) resistance windings. As the current flows, the windings heat up and the bimetallic spring bends, which opens the contact points and breaks the circuit. This deactivates the cold start valve.

The length of time current will flow through the resistance windings before the ground contacts open depends on coolant temperature. Maximum time for this unit is 12 seconds at –5°F (–21°C) or when the starter switch is released, whichever comes first.

AUXILIARY AIR REGULATOR

During cold starting, the auxiliary air regulator admits additional air into the intake manifold to speed up idle.

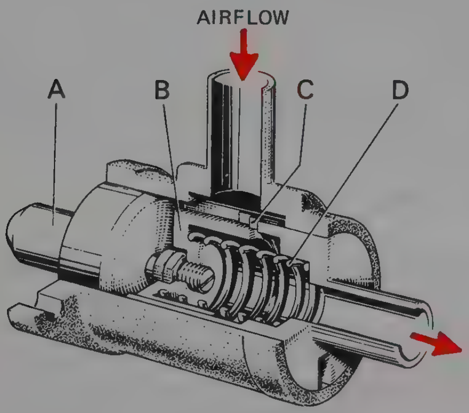


Fig. 22-21. Auxiliary air regulator valve speeds up engine idle during cold start conditions. A—Expanding element. B—Sliding regulator. C—Auxiliary air opening. D—Return spring.

The auxiliary air regulator, Fig. 22-21, is located in the engine water jacket with expanding element (A) in contact with the coolant.

At a temperature of –13°F (–25°C), the expanding element (A) has contracted and allowed spring (D) to force regulator (B) to open auxiliary air pipe passage (C) fully for maximum airflow (red arrows). As the coolant warms and heats the expanding element, the element forces the regulator back against spring pressure. At 140 °F (60 °C), the auxiliary airflow is completely shut off. Some units are heated electrically.

OVERALL SYSTEM

One type of intermittent electronic fuel injection is shown in Fig. 22-22. This is a schematic showing the overall system that contains sensors, controls, and other components similar to those just discussed. Study Fig. 22-22 until you are thoroughly familiar with the various units and the part they play in the overall operation. Note that this is a TWO-GROUP system. The four injectors are divided into TWO groups and actuated two at a time on an alternate basis.

Each group can inject fuel ONCE for each TWO crankshaft revolutions or, as is sometimes done in other

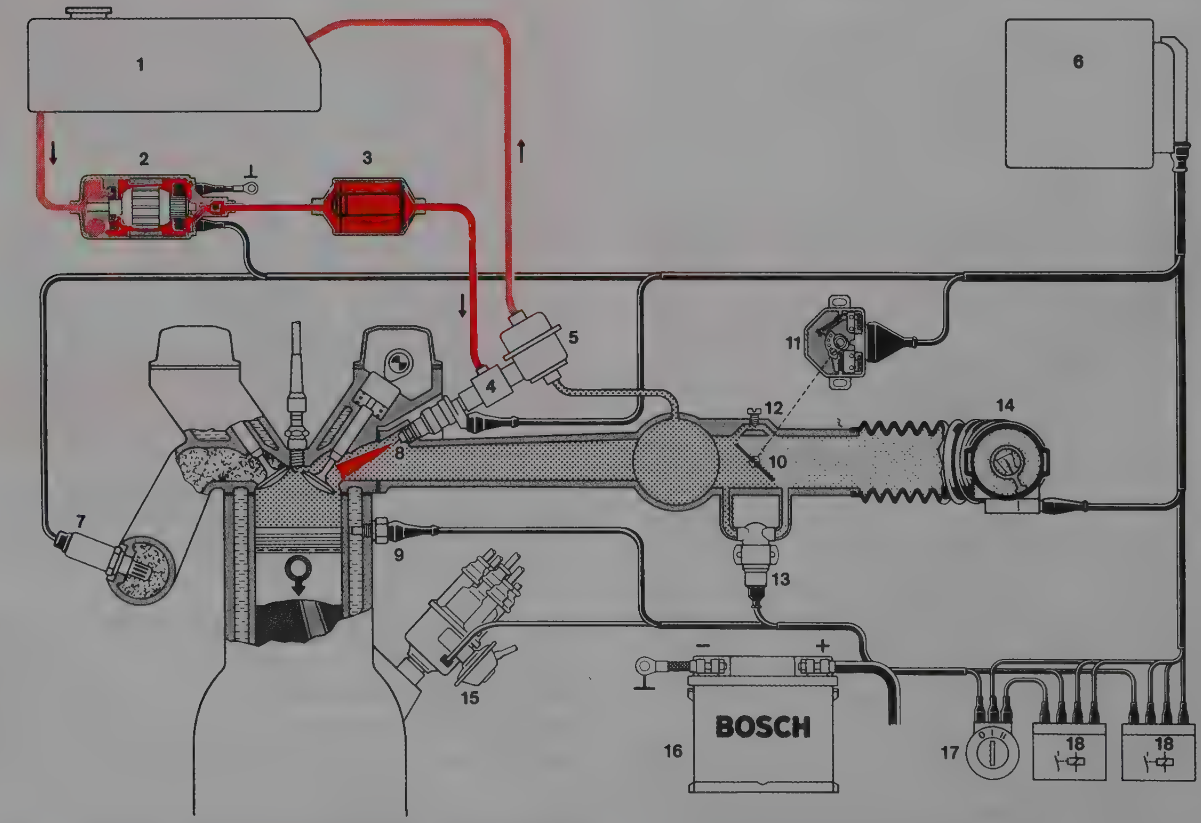


Fig. 22-22. Schematic of an intermittent fuel injection system. 1—Fuel tank. 2—Electric fuel pump. 3—Fuel filter. 4—Fuel distributor. 5—Pressure regulator. 6—Electronic control unit (ECU). 7—Oxygen sensor. 8—Injector. 9—Engine temperature sensor. 10—Throttle valve. 11—Throttle valve switch. 12—Idle speed adjusting screw. 13—Rotary idle actuator. 14—Hot wire mass airflow sensor. 15—Distributor. 16—Battery. 17—Ignition switch. 18—Relays. (Bosch)

systems, each group can inject ONE-HALF the required amount for every ONE revolution of the crankshaft.

CONTINUOUS FUEL INJECTION SYSTEM

As you recall, the intermittent fuel injection system operated the injectors for a short, measured period of time. During the remainder of the time, the injectors were held closed. They were not opened by fuel pressure but by a magnetic winding and armature.

In the continuous fuel injection system, the injectors feed some fuel AT ALL TIMES during engine operation. Fuel pressure in the fuel rail forces the injectors open. Unlike those of the intermittent system, these injectors are always open.

In continuous systems, the injector, Fig. 22-23, opens at 47 psi (324 kPa) fuel pressure. As long as the fuel metering slots are open, fuel pressure will exceed the 47 psi (324 kPa) level and fuel will flow continuously from the injector nozzle. The AMOUNT of fuel will vary, depending upon airflow volume. The injector, even at low fuel flow levels, will atomize the fuel properly. As with the intermittent system, these injectors will feed into the intake manifold (or cylinder head) near or in the intake valve port area.

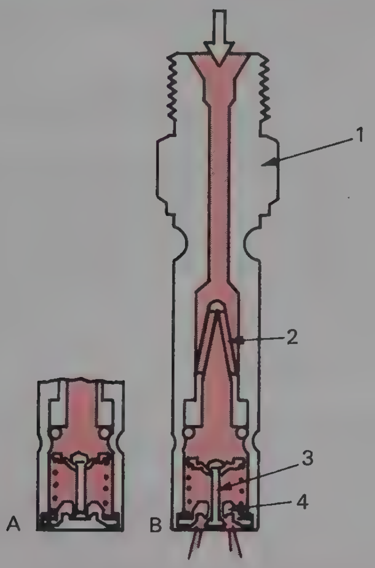


Fig. 22-23. One type of fuel injector used in a continuous fuel injection system. A—Closed (no fuel flow). B—Open. 1—Housing. 2—Fuel filter. 3—Valve needle. 4—Valve needle seat. (Bosch)

HOW FUEL FLOW IS CONTROLLED

Air passing into the intake manifold flows through an AIRFLOW SENSOR, Fig. 22-24. The sensor utilizes a hinged lever (H) that pivots on pivot rod (F). An airflow sensor plate (B) affixed to one end of the lever rides up and down in the center of the air venturi (A). A balance weight (D) is used to balance the lever and plate assembly, which allows the sensor plate (B) to "float" in the venturi.

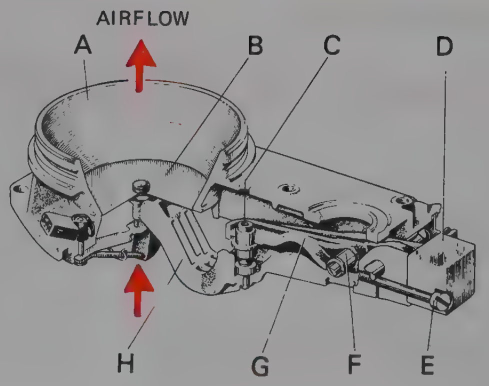


Fig. 22-24. Airflow sensor assembly. A—Air venturi. B—Airflow sensor plate. C—CO adjustment screw. D—Balance weight. E—Lock screw. F—Pivot shaft. G—Adjustment arm. H—Lever. (Volvo)

During part load operation, Fig. 22-25 (top), airflow has forced sensor plate (A) to rise a small amount. Note that the fuel distributor control valve has been raised somewhat by the lever (B). As the engine is accelerated, more and more air flows through the venturi raising the sensor plate higher and higher. Finally, at full load, Fig. 22-25 (bottom), the sensor plate is raised to its highest position (C). The lever has moved the fuel distributor control valve to the wide open position (D), permitting maximum fuel flow to the injectors. Remember — the airflow sensor controls the fuel distributor valve.

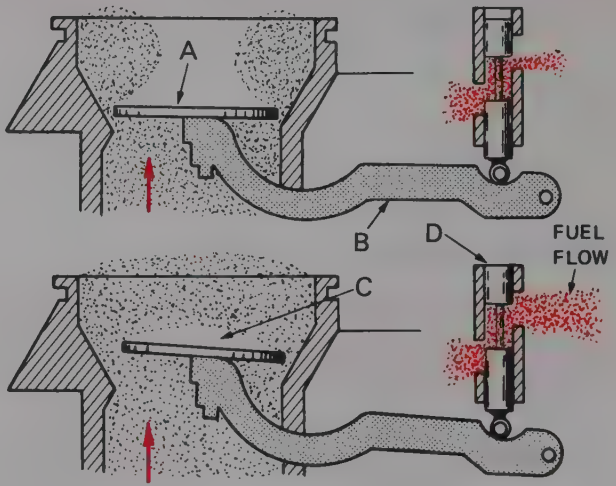


Fig. 22-25. Airflow sensor operation: Top. Part load operation. Bottom. Full load operation. A—Sensor down. B—Lever arm. C—Sensor up. D—Fuel valve open.

FUEL DISTRIBUTOR

The fuel distributor is actuated by the sensor plate lever. Fig. 22-26 shows an external view of a fuel distributor used on a four cylinder engine. Fuel enters at (A). After passing through the internal metering slots, it flows to each individual injector from outlets (F). Line pressure is controlled by the regulator (C), and excess fuel is returned to the tank by way of outlet (D). Fuel for the cold start injector flows from (E).

See Fig. 22-27 for a cross-sectional view of a fuel distributor.

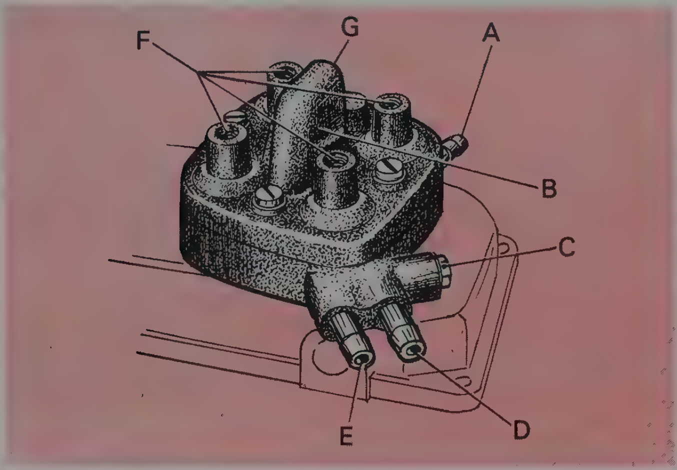


Fig. 22-26. Fuel distributor for a four cylinder engine. A—Fuel inlet. B—Fuel control unit. C—Line pressure regulator. D—Tank return. E—Cold start injector. F—Outlets to injector lines. G—To control pressure regulator. (Volvo)

PRESSURE REGULATOR VALVES

In order to provide a constant pressure drop through the fuel distributor metering slots, a pressure regulating valve is used for each injector outlet. The valves are built into the fuel distributor housing.

The constant pressure drop is needed to keep the amount of fuel injected directly proportional to the size of the metering slot opening.

Study the cross-sectional view of the fuel distributor in Fig. 22-27. Note the pressure regulator valve. The upper half (C) and the bottom half (A) are separated by a steel diaphragm (B). The lower half of each regulator (one for each injector outlet) is connected to the others, and all are connected into the fuel control outlet.

The fuel pressure in the lower half is maintained at 64 psi (441 kPa). The upper half has a spring (E) pushing down on the diaphragm with a pressure of 1.5 psi (10.3 kPa).

Fuel enters the upper half from the fuel distributor metering slot (F). Pressure rises in the top section until the pressure of the fuel, PLUS the pressure of the spring, forces the diaphragm downward. As it moves down, seat (D) opens and allows fuel to pass up outlet (G) to the injectors.

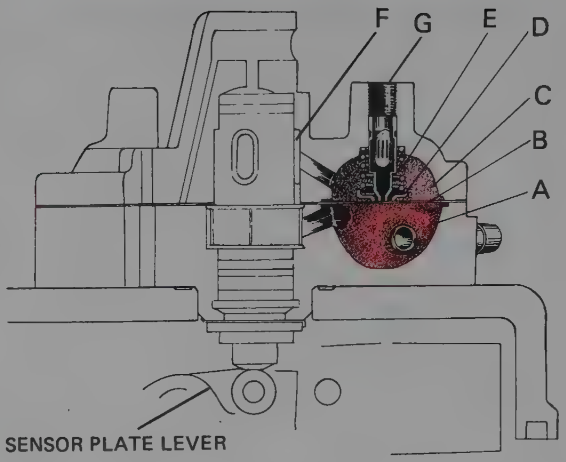


Fig. 22-27. Pressure regulating valve. Top half always maintains a pressure 1.5 psi (10.3 kPa) lower than bottom. A—Regulator bottom half. B—Steel diaphragm. C—Upper half. D—Seat. E—Spring. F—Metering slot. G—Outlet.

The diaphragm will move downward until increased flow from the metering slot is equalized by the increased flow to the injector.

The fuel pressure in the top half will always be 62.5 psi (430.9 kPa) due to spring (E) pressure on the diaphragm. This produces the desired pressure drop in the top half. Flow rate change through the metering slots will immediately cause a shift in diaphragm position until upper and lower pressures are returned to the 1.5 psi (10.3 kPa) difference.

COMPLETE AIR-FUEL CONTROL UNIT

Fig. 22-28 pictures the complete air-fuel control unit, consisting of the airflow sensor, fuel distributor, pressure regulator valve, and related parts. Note that there is pressure (black) in the control chamber (F) above the control plunger (G). This controlled pressure (around 52.2 psi or 360 kPa) is needed to dampen sensor plate lever (B) movement so that, upon sudden acceleration, the sensor plate is not raised beyond the point that the airflow will maintain.

CONTROL PRESSURE REGULATOR

The control pressure regulator maintains a steady pressure of 52.2 psi (360 kPa) in chamber (F) above control plunger (G) in Fig. 22-28 when the engine is at normal operating temperature. Fig. 22-29, heating coil (C) causes bimetallic spring (D) to alter pressure on spring (B), which changes spring pressure on the diaphragm valve. This causes a lowering of control pressure which, in turn, will allow the sensor plate lever

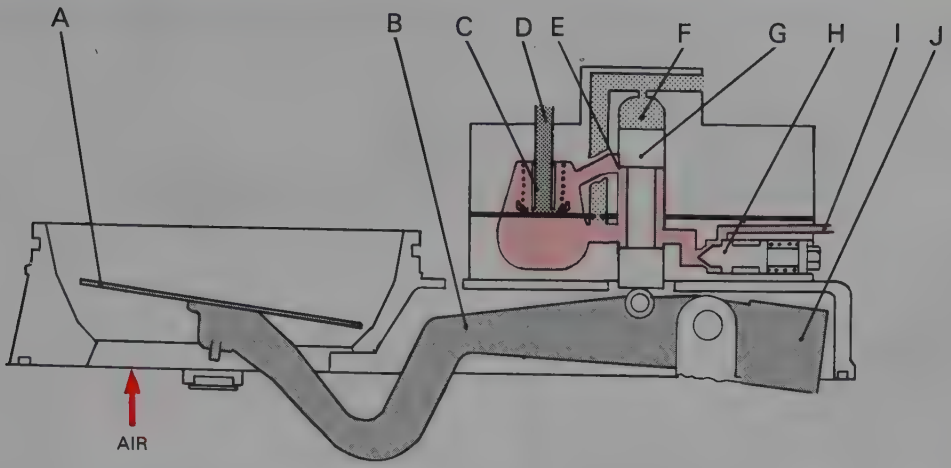


Fig. 22-28. Complete air-fuel control unit. A—Airflow sensor plate. B—Sensor plate lever. C—Pressure regulating valve. D—To injector. E—Control plunger head. F—Control pressure. G—Control plunger. H—Line pressure regulator. I—Fuel inlet from tank. J—Balance weights. (Volvo)

to shove the control plunger farther up. This allows extra fuel to flow through the metering slots. As the engine warms, normal fuel pressure is resumed.

COMPLETE FUEL SYSTEM

A schematic of the entire continuous fuel injection system is illustrated in Fig. 22-30.

Study all parts and relate their individual functions to that of the overall system. Keep at it until the functions are clear!

VARIATIONS

We have covered the two basic systems in current use—the INTERMITTENT and the CONTINUOUS INJECTION SYSTEMS. There are some variations in between. Theory and operation, however, are basically the same.

FUEL INJECTION SYSTEM SERVICE

To properly diagnose, test, and service the fuel injection system, you should have the proper tools and test instruments. You also should have, and USE, test and service specifications for the specific system.

DANGER, DANGER!

BEFORE LOOSENING ANY FUEL INJECTION FUEL LINES, ALWAYS REMOVE (BLEED) THE PRESSURE FROM THE LINES! SOME MAKERS RECOMMEND DISCONNECTING THE FUEL PUMP, THEN RUNNING THE ENGINE UNTIL IT STOPS. FOLLOWING STOPPING, ENGINE SHOULD BE CRANKED OVER A FEW TIMES. DISCONNECT BATTERY. LINES SHOULD THEN BE CRACKED (BARELY LOOSENED) TO CHECK FOR ANY POSSIBLE PRESSURE.

SOME SYSTEMS USE A SPECIAL "SCHRADER" BLEED VALVE. DISCONNECT BATTERY AND USE VALVE TO BLEED OFF PRESSURE.

ANOTHER TECHNIQUE INVOLVES DISCONNECTING THE BATTERY THEN SLOWLY CRACKING A FITTING TO RELEASE PRESSURE.

WHEN CRACKING FITTINGS OR USING SCHRADER VALVE, COVER THE AREA WITH A SHOP CLOTH TO CATCH AND CONTAIN ANY FUEL THAT MAY SPRAY OUT. IMMEDIATELY DISPOSE OF THE FUEL-SOAKED CLOTH. WEAR PROTECTIVE GOGGLES. KEEP AN APPROVED FIRE EXTINGUISHER HANDY.

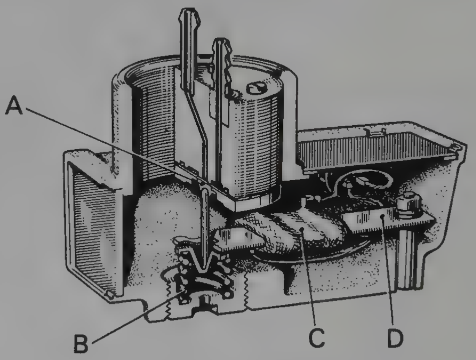


Fig. 22-29. Control pressure regulator. A—Diaphragm valve. B—Spring. C—Coil. D—Bimetallic spring.

SYSTEM PROBLEM DIAGNOSIS

When experiencing system problems, always give the complete system an initial inspection before beginning

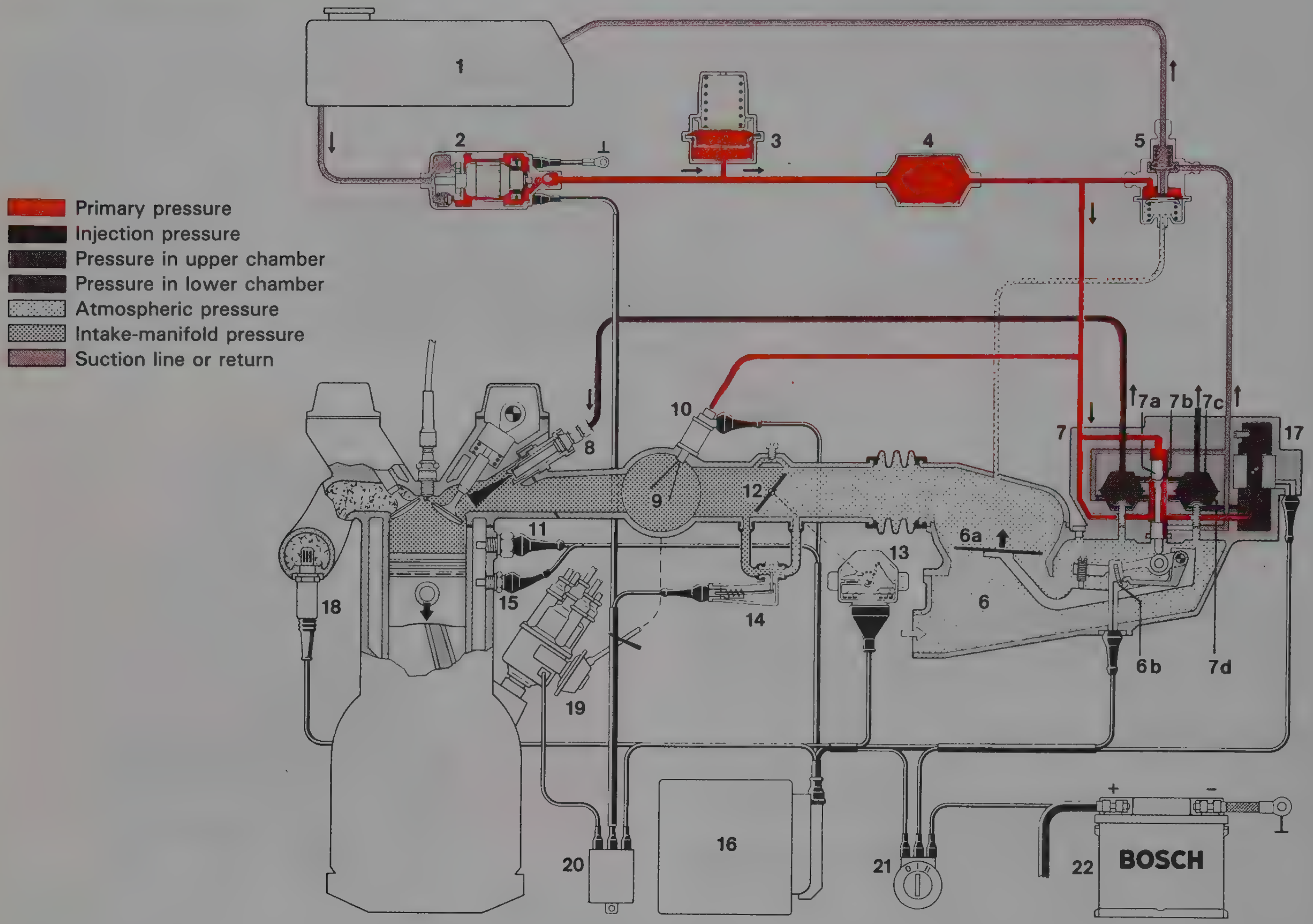


Fig. 22-30. Schematic diagram of a continuous fuel injection system. 1—Fuel tank. 2—Fuel pump. 3—Fuel accumulator. 4—Fuel filter. 5—Primary pressure regulator. 6—Air flow sensor. 6A—Sensor plate. 6B—Potentiometer. 7—Fuel distributor. 7A—Control plunger. 7B—Control edge. 7C—Upper chamber. 7D—Lower chamber. 8—Fuel injection valve. 9—Intake manifold. 10—Cold start valve (injector). 11—Thermal time switch. 12—Throttle valve. 13—Throttle valve switch. 14—Auxiliary air device. 15—Engine temperature sensor. 16—Electronic control unit (ECU). 17—Electro-hydraulic pressure actuator. 18—Oxygen sensor. 19—Distributor. 20—Control relay. 21—Ignition switch. 22—Battery. (Bosch)

diagnostic tests. Also, before blaming the fuel injection system, check whether or not some other system, such as ignition, electrical, or starting, is causing the problem. Question the car owner regarding the problem - when it occurs, how it sounds, effects engine performance, etc. Road test car, if necessary, to confirm the presence of a problem.

INITIAL INSPECTION

Prior to starting diagnostic tests, give the system an initial visual inspection. This will often pinpoint the problem. Perform the following steps:

1. Check all fuel lines for tight fittings, cracks, pinched, or collapsed sections.
2. Check vacuum lines for poor connections, improper connections, kinks, or leaks.
3. Check wiring for clean, tight connectors, improper connections, shorting, frayed or broken wires, or a blown fuse.
4. Inspect any mechanical linkage for freedom of operation and correct adjustment.
5. Check air intake and air cleaner for clogging or obstructions.
6. Check level, type, and octane rating of fuel being used.
7. Inspect related emission controls for possible malfunction.
8. Check exhaust system for kinks or clogging.

TYPICAL INJECTION SYSTEM PROBLEMS

Fuel injection problems are much like those experienced in a carbureted vehicle. The causes and corrections are, of course, quite different. Some typical injection system problems would be:

1. Engine will not start under any conditions.
2. Engine will start, but stalls.

3. Engine starts hard (must be cranked excessively).
4. Engine idles rough.
5. Engine stays on fast idle.
6. No fast idle.
7. Engine hesitates on acceleration.
8. Engine cuts out or misfires at all speeds.
9. Engine performs poorly at high speed.
10. Excessive fuel consumption.
11. Poor low speed operation.
12. Engine backfires.
13. Loss of power.
14. Engine surges (fast-slow-fast).
15. Engine emits black smoke.

FUEL INJECTOR SERVICE

Remove injectors as recommended. Use care to avoid damage. Wipe off exterior but do NOT immerse in solvent of any kind. The injector is electrically operated. Solvent can damage the solenoid windings. Fig. 22-31 shows the method used to remove one injector setup.

Injectors can be checked for proper functioning, spray pattern, fuel output, and freedom from leakage. Use proper equipment and recommended test procedures. BE CAREFUL OF FIRE. WEAR GOGGLES. Look at Fig. 22-32.

Fuel injectors should normally be serviced as a unit. If defective, replace with a new one. Make certain replacement is correct.

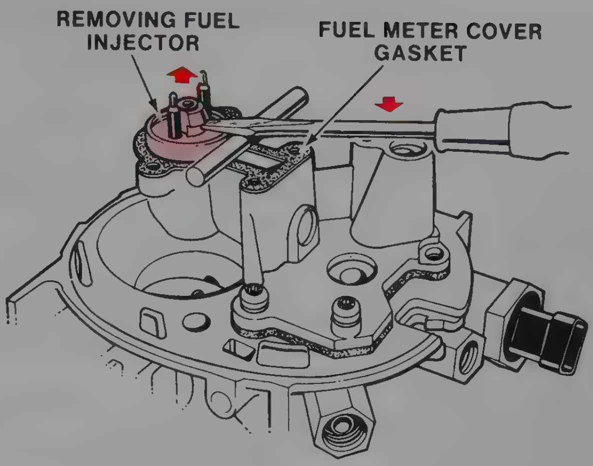


Fig. 22-31. Removing fuel injector from throttle body. Use care to avoid damaging unit. (Chevrolet)

SPECIAL CAUTIONS FOR FUEL INJECTION SERVICE!

When testing or servicing a fuel injection system, certain precautions are necessary. Always double-check for any recommended cautions for the exact system being serviced!

The following precautions apply to many systems:

1. Disconnect the battery before working on the system.

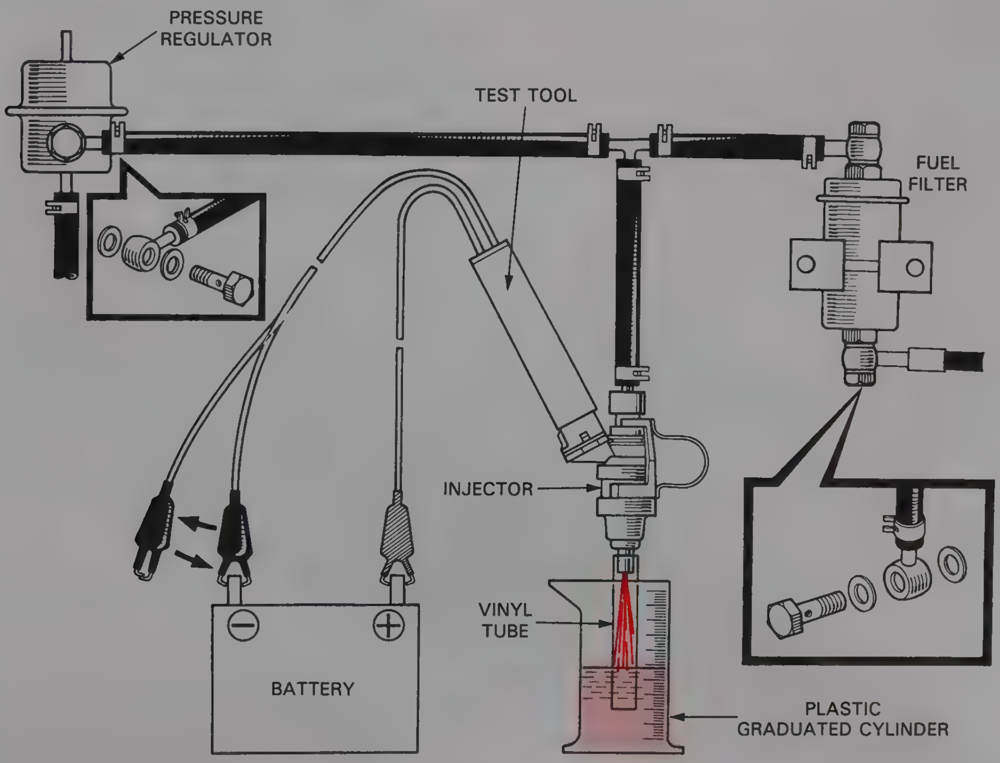


Fig. 22-32. Testing fuel injector flow rate. Note vinyl tube around injector to restrict fuel spray to plastic cylinder. (Toyota)

2. Disconnect the battery when being charged.
3. Do not run the engine when battery is disconnected.
4. Turn off ignition switch before connecting or disconnecting electronic control unit.
5. Before removing battery cable connections or fuses, turn ignition switch OFF.
6. Do not apply voltage to the electronic control unit (module) with ignition switch in ON position.
7. Do not apply voltage to or ground the electronic control unit circuits UNLESS specifically called for in manual.
8. Do not subject electronic control unit to excessive heat such as found in some paint drying ovens.
9. Use extreme cleanliness on all fuel line work as the slightest bit of dirt can jam some injectors.
10. Do not use a fast charger to start engine.
11. Use only high quality, properly designed replacement lines and hoses for the fuel delivery system. Torque fittings as directed.
12. Upon completion of service, always check systems for gasoline leaks!
13. Use approved test equipment specifically designed for the job at hand.
14. Remember that modern fuel injection systems are closely tied in with the emission controls and that proper functioning is dependent upon overall system soundness.
15. Never attempt service procedures unless you have proper training, and a good, manufacturer's service manual for the system at hand. You must also have recommended test equipment. Improper service procedures can cause EXTENSIVE and EXPENSIVE system damage!

A schematic of a complete electronically controlled fuel injection system is illustrated in Figs. 22-22 and 22-60.

DIESEL FUEL INJECTION

The diesel engine injection system differs from the mechanical gasoline fuel injection in three respects:

1. Diesel fuel is injected directly into the cylinder combustion area.
2. Injection must be timed to the compression stroke, and the fuel pressure required is much, much higher.
3. Fuel must be injected into the combustion chamber area at the height of compression. This requires tremendous pressure.

The system uses an engine driven (by chain, belt, direct connection) injector pump.

An overall view of a diesel fuel injection system is shown in Fig. 22-33. Fig. 22-34 is a schematic showing the principles of a typical diesel injection system. Trace the flow from tank to injectors.

A cutaway view of a four cylinder automotive diesel engine is pictured in Fig. 22-35. Note that the fuel injection pump is driven by a cogged (spur or toothed) belt.

A V-8 diesel engine is shown in Fig. 22-36.

A cross-sectional view of a fuel injector in place in the cylinder head is illustrated in Fig. 22-37.

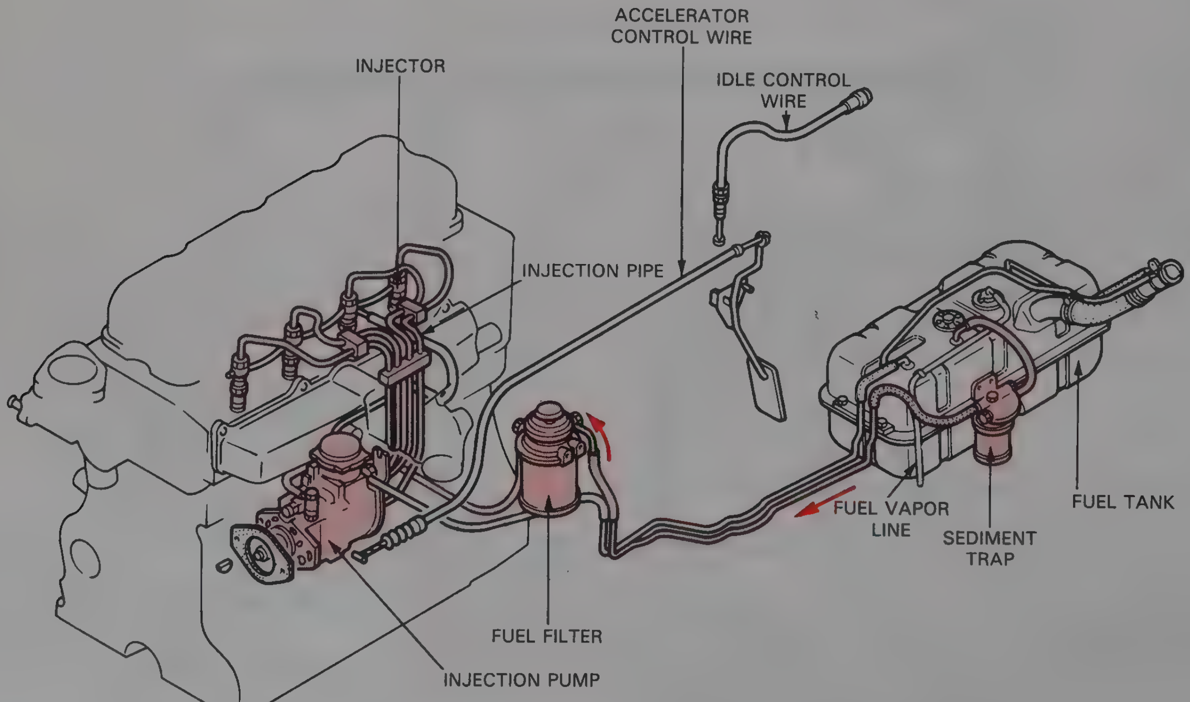


Fig. 22-33. Four-cylinder diesel engine fuel system. (Mazda)

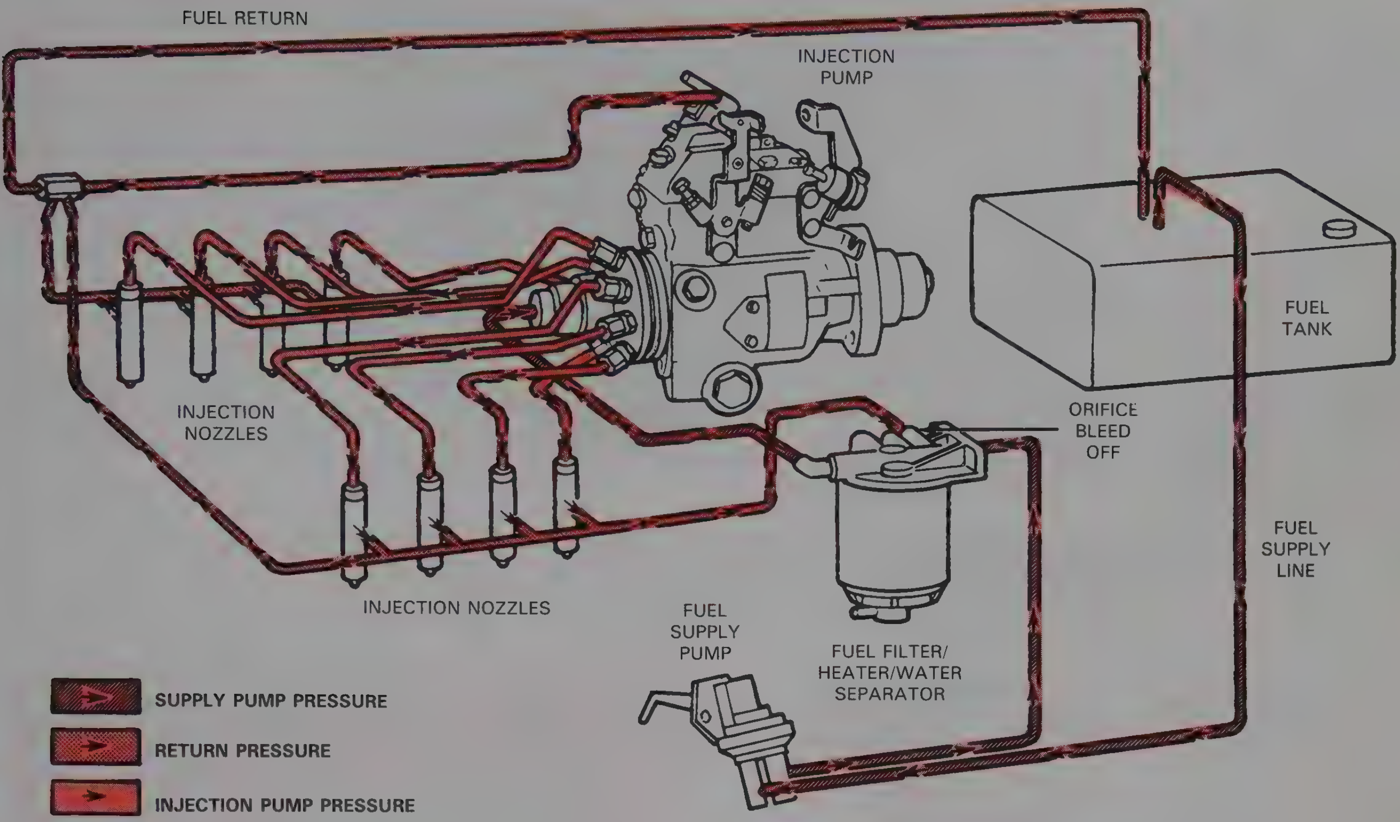

FUEL RETURN
INJECTION PUMP
FUEL TANK
INJECTION NOZZLES
ORIFICE BLEED OFF
FUEL SUPPLY LINE
INJECTION NOZZLES
FUEL SUPPLY PUMP
FUEL FILTER/ HEATER/WATER SEPARATOR
SUPPLY PUMP PRESSURE
RETURN PRESSURE
INJECTION PUMP PRESSURE

Fig. 22-34. Schematic of one type of diesel fuel injection system. This system uses a rotary injection pump. (Ford)

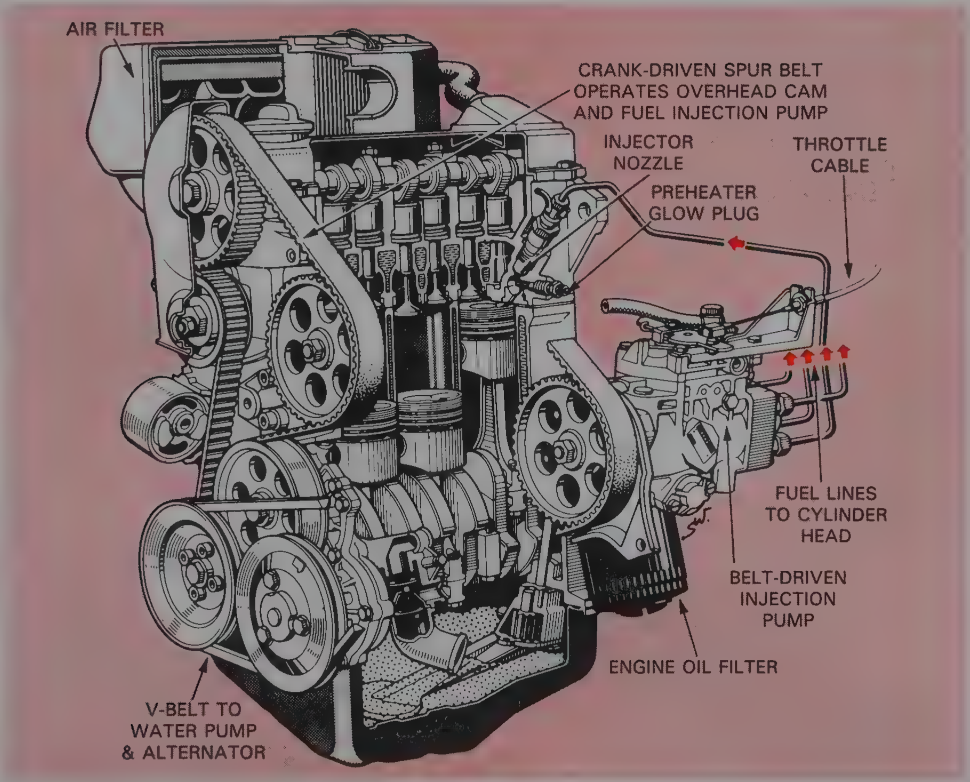

AIR FILTER
CRANK-DRIVEN SPUR BELT OPERATES OVERHEAD CAM AND FUEL INJECTION PUMP
INJECTOR NOZZLE
THROTTLE CABLE
PREHEATER GLOW PLUG
FUEL LINES TO CYLINDER HEAD
BELT-DRIVEN INJECTION PUMP
ENGINE OIL FILTER
V-BELT TO WATER PUMP & ALTERNATOR

Fig. 22-35. A four-cylinder, 1.5-liter, diesel engine. This engine develops 48 (SAE Net) hp at 5000 rpm. (Volkswagen)

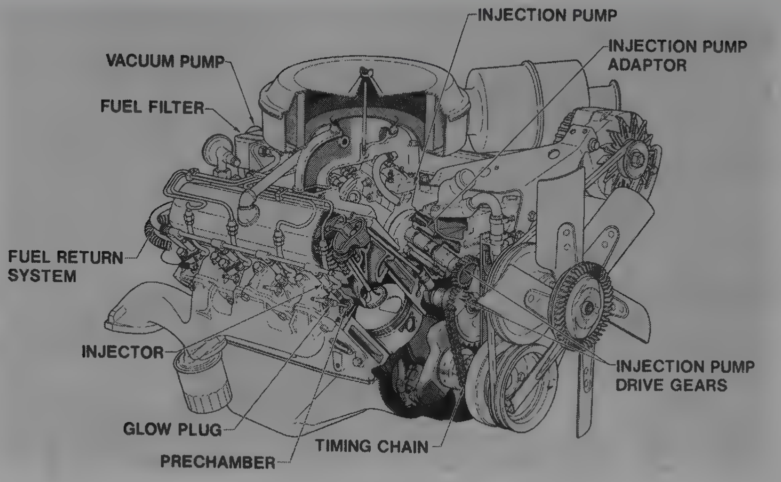

INJECTION PUMP
INJECTION PUMP ADAPTOR
VACUUM PUMP
FUEL FILTER
FUEL RETURN SYSTEM
INJECTOR
GLOW PLUG
PRECHAMBER
TIMING CHAIN
INJECTION PUMP DRIVE GEARS

Fig. 22-36. An eight cylinder diesel engine of 350 cu. in. displacement. This engine develops 120 hp at 3,600 rpm. Speed is limited to 4,000 rpm. Compression ratio is 22.3 to 1. (Oldsmobile)

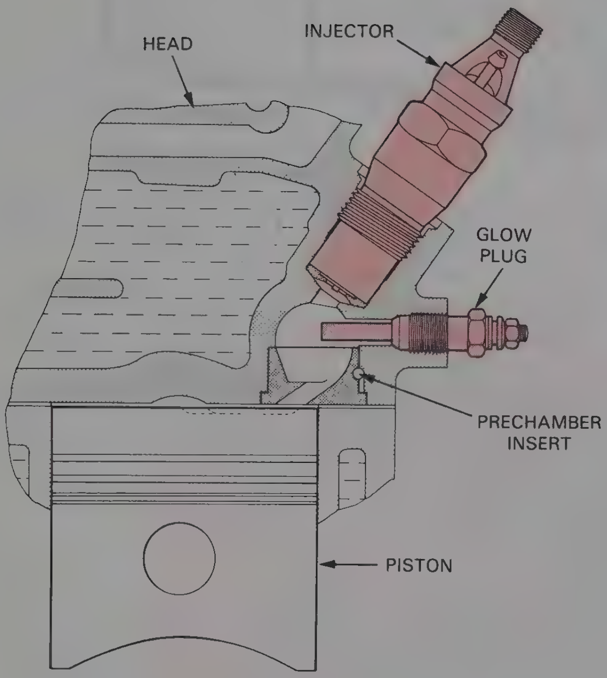

HEAD
INJECTOR
GLOW PLUG
PRECHAMBER INSERT
PISTON

Fig. 22-37. Diesel injector and glow plug arrangement. (Champion)

DIESEL INJECTOR SERVICE

The diesel injector must be serviced with the proper tools. Injectors are tested for leaks, opening pressure, spray pressure, chatter, spray jet shape, and leakage.

One injector design is shown in Fig. 22-38. Use recommended disassembly techniques. Remember, when disassembling system lines and parts, always cap lines, nozzles, and pump fittings to prevent entry of dirt. Always wipe fittings before reassembly with a clean, LINT-FREE cloth.

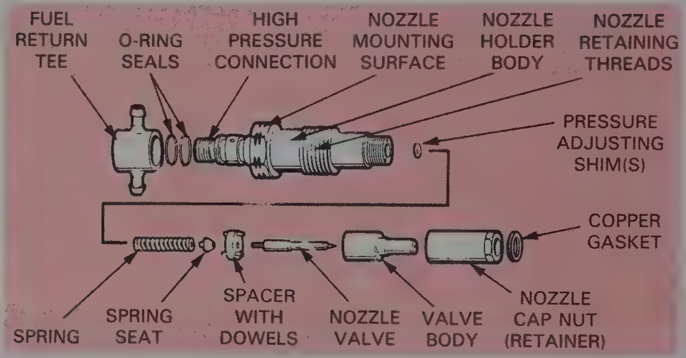

FUEL RETURN TEE
O-RING SEALS
HIGH PRESSURE CONNECTION
NOZZLE MOUNTING SURFACE
NOZZLE HOLDER BODY
NOZZLE RETAINING THREADS
PRESSURE ADJUSTING SHIM(S)
COPPER GASKET
SPRING
SPRING SEAT
SPACER WITH DOWELS
NOZZLE VALVE
VALVE BODY
NOZZLE CAP NUT (RETAINER)

Fig. 22-38. Exploded view of a diesel injector and holder assembly. (International/Navistar)

Keep all parts of each injector nozzle together as they are carefully matched. NEVER MIX PARTS. Clean thoroughly in a sonic bath cleaner or some other suitable cleaner. Fig. 22-39 illustrates the use of a special cleaning tray designed to keep the parts of each injector separate. The tray is lowered into the clean-

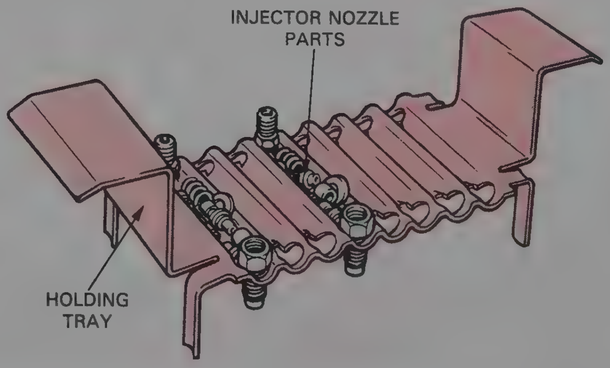

INJECTOR NOZZLE PARTS
HOLDING TRAY

Fig. 22-39. This handy cleaning tray keeps parts of each injector separate. Never mix parts. (Chevrolet)

ing bath. When thoroughly clean (all carbon removed), reassemble as recommended. For manual cleaning, use a wooden stick or soft brass brush to prevent damaging nozzle parts.

When testing injectors, use a special test liquid instead of diesel fuel. The test liquid will minimize skin problems and is stable in relation to corrosion inhibition.

Use proper test equipment such as is shown in Fig. 22-40. It is advisable to shroud the injector nozzle with a clear, protective plastic shield. The use of such a shroud is pictured in Fig. 22-41. Spray pattern should meet manufacturer's recommendations.

Injectors should also be checked for nozzle tightness. Using a test stand, build pressure in injector (nozzle tip dry) to slightly below the actual opening pressure (around 150 psi or 1 034 kPa). Hold for recommended time (a few seconds) and check nozzle tip. One maker's acceptable indicators are pictured in Fig. 22-42.

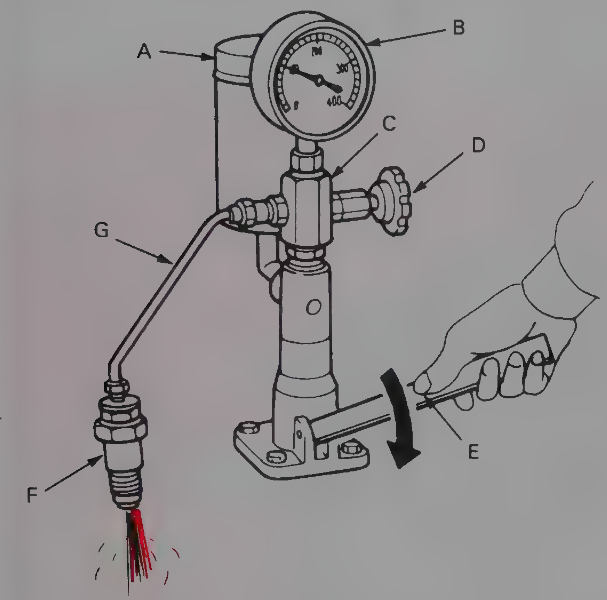


Fig. 22-40. Tool for testing injector. A—Pressure Tank. B—Pressure gauge. C—Control valve. D—Control valve knob. E—Operating lever. F—Injection nozzle assembly. G—Pressure pipe assembly. (Nissan)

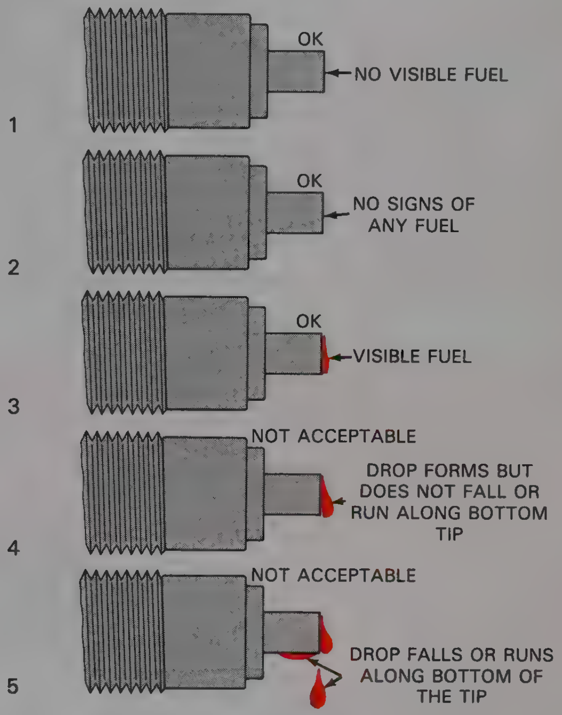

1
OK
NO VISIBLE FUEL
2
OK
NO SIGNS OF ANY FUEL
3
OK
VISIBLE FUEL
4
NOT ACCEPTABLE
DROP FORMS BUT DOES NOT FALL OR RUN ALONG BOTTOM TIP
5
NOT ACCEPTABLE
DROP FALLS OR RUNS ALONG BOTTOM OF THE TIP

Fig. 22-42. Checking injector nozzle for tightness (sealing ability). After maintaining recommended pressure for a few seconds, nozzle should not show signs of excessive leakage, as in 4 and 5. (Oldsmobile)

When installing injectors in the engine, where required, coat threads with proper lubricant. Use new gaskets and tighten to specified torque. On injectors

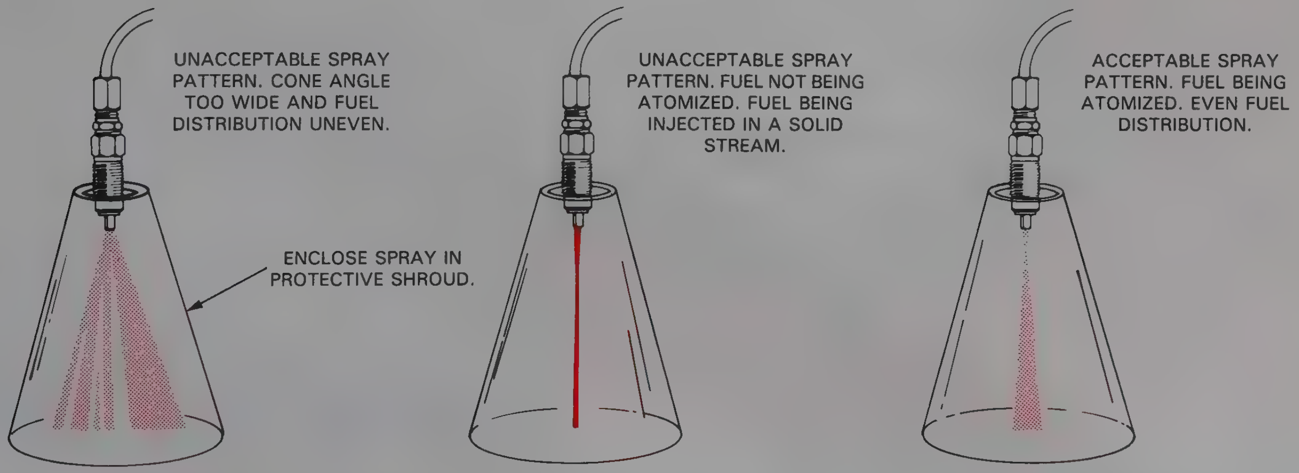

UNACCEPTABLE SPRAY PATTERN. CONE ANGLE TOO WIDE AND FUEL DISTRIBUTION UNEVEN.
ENCLOSE SPRAY IN PROTECTIVE SHROUD.
UNACCEPTABLE SPRAY PATTERN. FUEL NOT BEING ATOMIZED. FUEL BEING INJECTED IN A SOLID STREAM.
ACCEPTABLE SPRAY PATTERN. FUEL BEING ATOMIZED. EVEN FUEL DISTRIBUTION.

Fig. 22-41. Testing diesel injector nozzle spray pattern. Note use of protective shroud. (Cadillac)

such as shown in Fig. 22-38, place wrench on large hex when tightening. Install fuel line fittings and torque. Check for leaks following engine startup.

WARNING–DANGER!

NEVER POINT AN INJECTION NOZZLE TOWARDS YOUR BODY WHEN CONDUCTING TESTS. USE A CLEAR PROTECTIVE SHROUD AROUND INJECTOR NOZZLE. NEVER GET YOUR HANDS IN FRONT OF THE NOZZLE. WHEN SPRAYING, THE FUEL LEAVES THE NOZZLE WITH FEARSOME FORCE. IT CAN LITERALLY DRILL THROUGH FLESH, CREATING A SEVERE INJURY WITH CHANCES OF BLOOD POISONING. USE CARE ALSO WHEN WORKING ON INJECTION PUMP OR INJECTOR LINE FITTINGS! WEAR PROTECTIVE GOGGLES! CRACK (BARELY LOOSEN) FITTINGS AND BLEED (REMOVE) PRESSURE.

INJECTOR PUMP SERVICE

An IN-LINE type of injection pump is portrayed in Fig. 22-43. In this type pump, each injector is served by a separate cylinder-plunger-cam arrangement.

A DISTRIBUTOR type pump is shown in Fig. 22-44. Note that a single set of pump plungers generate the required pressure. Fuel is fed from the pump to a fuel distributor rotor. As the rotor revolves, it distributes fuel to the various outlets as required. Study the part arrangement.

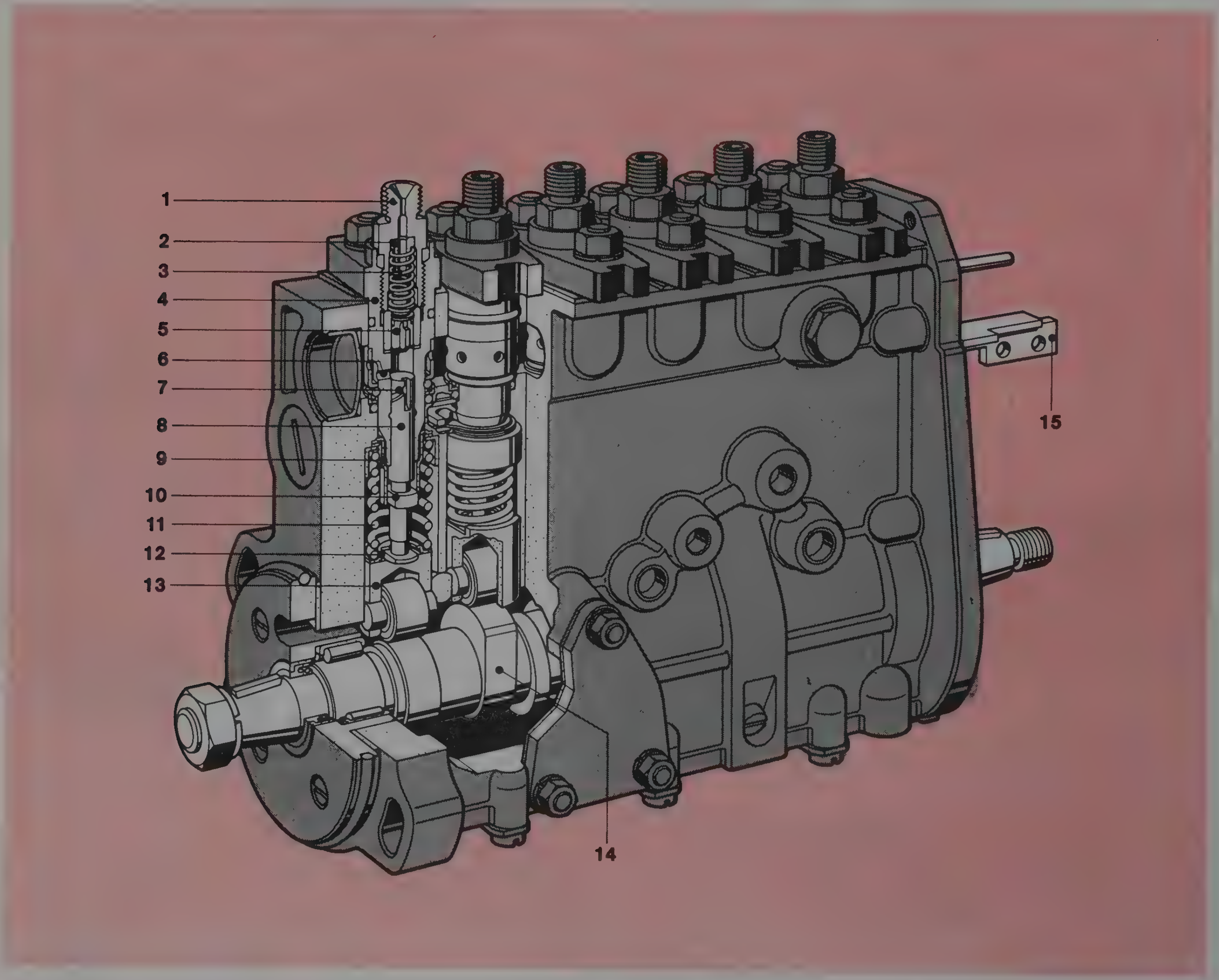


Fig. 22-43. One type of in-line fuel injection pump. Study parts. 1–Delivery valve holder. 2–Filler piece. 3–Delivery valve spring. 4–Pump barrel. 5–Delivery valve. 6–Inlet and spill port. 7–Helix. 8–Pump plunger. 9–Control sleeve. 10–Plunger control arm. 11–Plunger return spring. 12–Spring seat. 13–Roller tappet. 14–Cam. 15–Control rod. (Bosch)

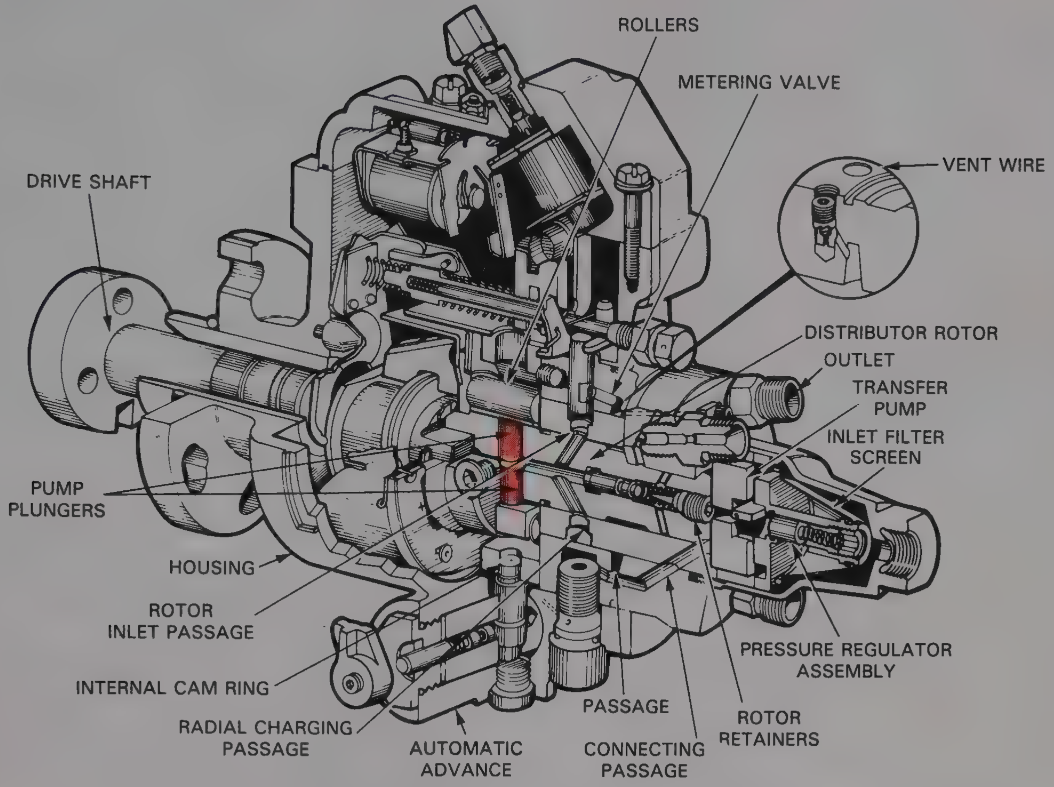

ROLLERS
METERING VALVE
VENT WIRE
DRIVE SHAFT
DISTRIBUTOR ROTOR
OUTLET
TRANSFER PUMP
INLET FILTER SCREEN
PUMP PLUNGERS
HOUSING
ROTOR INLET PASSAGE
PRESSURE REGULATOR ASSEMBLY
INTERNAL CAM RING
PASSAGE
ROTOR RETAINERS
RADIAL CHARGING PASSAGE
AUTOMATIC ADVANCE
CONNECTING PASSAGE

Fig. 22-44. Rotary type diesel injection pump. Note double pump plungers. As rotor turns, it passes fuel to various injectors. (Ford)

As with the injectors, proper injection pump test tools are essential. Special training in injection pump repair is required. Never disassemble a pump unless qualified. Great care and cleanliness is absolutely necessary! Fig. 22-45 shows specialists testing fuel injection pumps. Many shops specialize in pump rebuilding and testing.

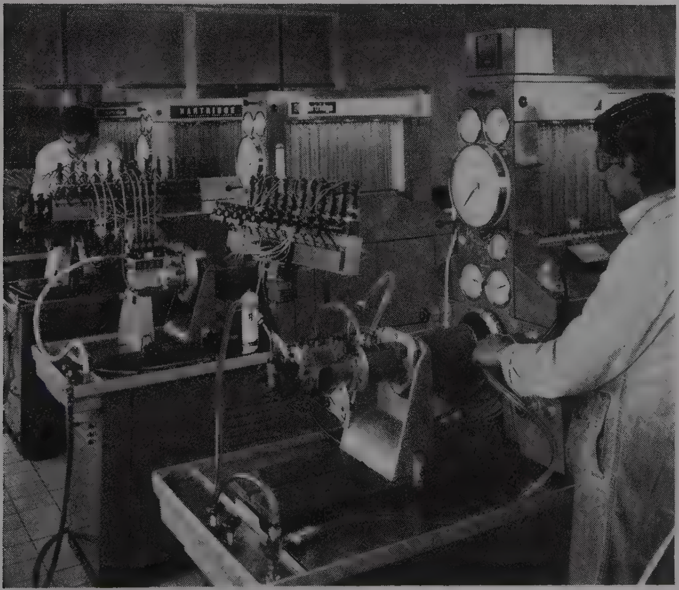


Fig. 22-45. Injection pump repair shop. Note test benches. When actually testing, wear protective goggles. (Hartridge)

CONTROL LINKAGE ADJUSTMENT

Accurate control linkage adjustments are of vital importance. Follow manufacturer's recommendations.

GLOW PLUGS

Glow plugs are used for cold starting because compression heat is not high enough to properly ignite the fuel charge. Plug temperature can range from 1832°F to 2192°F (1000°C to 1200°C).

A glow plug is a low voltage heating element, which is commonly located in the intake manifold or the combustion chamber. When the ignition is turned on, (engine coolant temperature below a certain point), the glow plugs are energized and quickly reach full heat. Many glow plug systems reach peak heat in just a few seconds. The engine may then be started. Some glow plugs cycle on and off until the engine reaches normal operating temperature. Three types of glow plugs are illustrated in Fig. 22-46.

A glow plug wiring harness (A), and wiring circuit (B), are shown in Fig. 22-47. Never bypass the power relay to glow plugs because a constant power source will cause many types to quickly overheat and burn out.

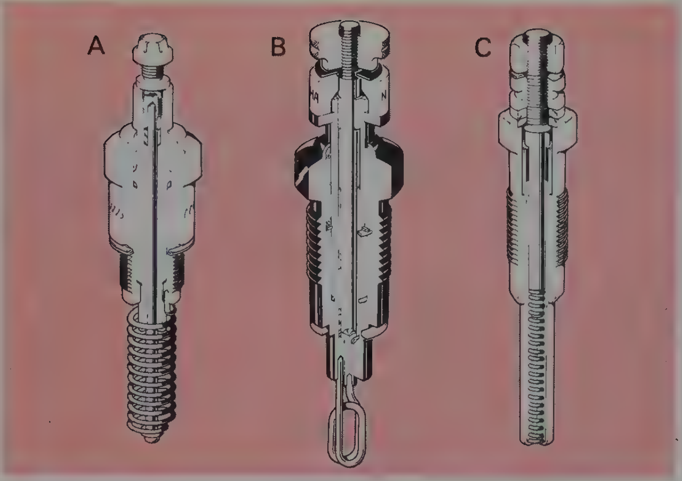


Fig. 22-46. Three types of glow plugs. A—Manifold heater type. B—Open element type. C—Sheathed element type. (Champion)

WARNING!

WHEN WORKING AROUND GLOW PLUGS: REMEMBER THAT, ON SOME SYSTEMS USING HEAVY, UNINSULATED CONNECTING WIRES, CURRENT FLOWS THROUGH THE CONNECTING RESISTOR WIRES FOR ALMOST TWO MINUTES AFTER THE CONTROL LIGHT GOES OUT (UNLESS ENGINE IS STARTED). THE WIRES CAN BE VERY HOT! KEEP HANDS AND ARMS AWAY!

SOME PROBLEMS

Defective glow plugs or glow plug system problems can cause cold start problems.

The injectors, if dirty, damaged, or sticking can cause rough running, loss of power, knocking, and smoking.

In some instances, the injection pump timing can be off resulting in very noisy engine operation. Internal pump problems can cause heavy exhaust smoking, surging, rough running, and/or noise. Binding or improperly adjusted linkage can affect idle speed range.

It is possible for the engine to continue running even after the key is turned off. This can result from wiring problems, vacuum leaks, incorrect vacuum connections, damaged vacuum control unit, defective vacuum pump, or fuel solenoid not returning fuel valve to the closed position. To stop the engine, depending on the system of course, disconnect the wire to the fuel solenoid. If the engine still continues to run, interrupt the flow of fuel from the tank to the injection pump.

DIESEL FUEL SYSTEM SERVICE

Line filters must be changed at required or recommended intervals. Diesel fuel, at times, can be somewhat dirty and occasionally has some water content. Keep fuel tank clean.

Water is very harmful to the injection pump. Many filters have both a water trap and water sensor to alert the driver to the presence of water. When water is present, drain it off at once! Fig. 22-48 shows a cutaway view of a diesel system filter with a water warning sensor, drain, and fuel heater.

SERVICE CAUTIONS

Diesel systems can vary widely in some respects. Be certain you understand the system at hand and that you have the proper tools and "specs." Never steam clean or wash injection pumps with engine running or with pump warm. Pump parts are very closely fitted. A sudden temperature change can warp the unit and cause part binding.

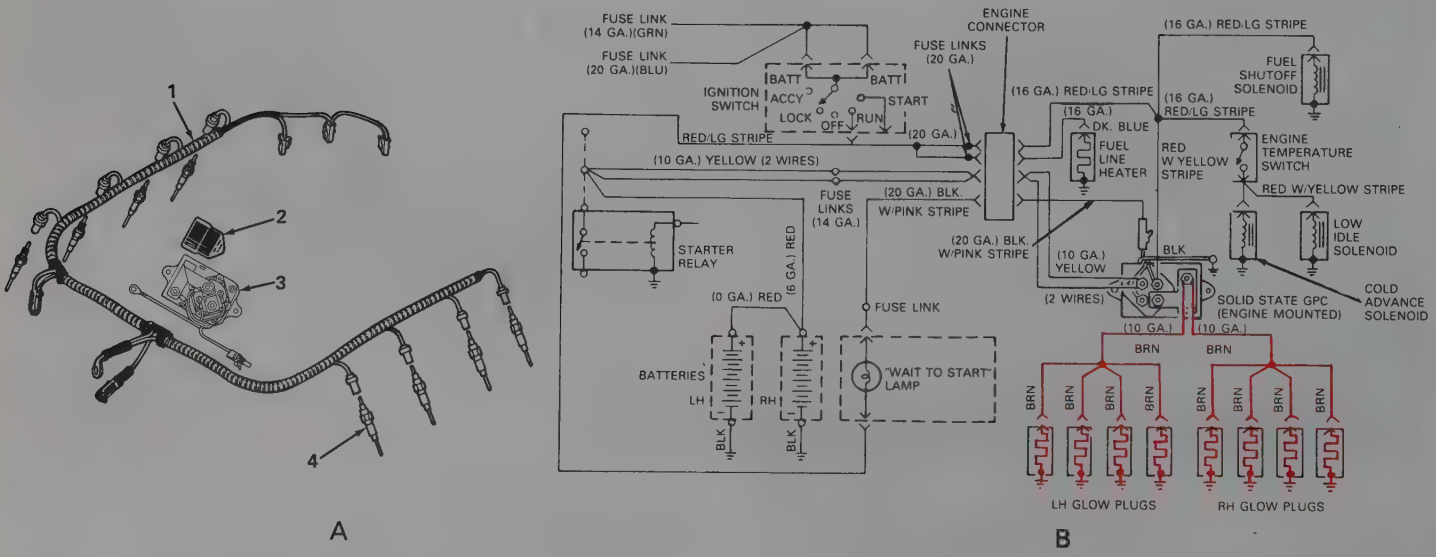

1
2
3
4
A
FUSE LINK (14 GA.)(GRN)
FUSE LINK (20 GA.)(BLU)
IGNITION SWITCH
BATT
BATT
ACCY
START
LOCK
OFF
RUN
ENGINE CONNECTOR
FUSE LINKS (20 GA.)
(16 GA.) RED/LG STRIPE
(16 GA.) RED/LG STRIPE
FUEL SHUTOFF SOLENOID
(16 GA.) RED/LG STRIPE
(16 GA.)
DK. BLUE
RED/LG STRIPE
(20 GA.)
(10 GA.) YELLOW (2 WIRES)
FUEL LINE HEATER
RED W YELLOW STRIPE
ENGINE TEMPERATURE SWITCH
RED W/YELLOW STRIPE
FUSE LINKS (14 GA.)
(20 GA.) BLK. W/PINK STRIPE
STARTER RELAY
(6 GA.) RED
(20 GA.) BLK. W/PINK STRIPE
(10 GA.) YELLOW
BLK
LOW IDLE SOLENOID
(0 GA.) RED
FUSE LINK
(2 WIRES)
SOLID STATE GPC (ENGINE MOUNTED)
COLD ADVANCE SOLENOID
(10 GA.)
(10 GA.)
BRN
BRN
BATTERIES
LH
RH
BLK
BLK
"WAIT TO START" LAMP
BRN
BRN
BRN
BRN
BRN
BRN
BRN
BRN
LH GLOW PLUGS
RH GLOW PLUGS
B

Fig. 22-47. A—Diesel glow plugs and harness. 1—Harness. 2—Glow plug controller cover. 3—Glow plug controller. 4—Glow plug. B—Glow plug electrical circuit. Note that this system is for a four-stroke cycle, V-8, diesel engine. (International/Navistar)

TURBOCHARGERS

Turbochargers (sometimes called turbosuperchargers) are superchargers that are driven by the force of the engine exhaust. They literally ram the air into the cylinders by raising the pressure of the air in the intake manifold. Fig. 22-49 is a schematic showing the principle of a turbocharger.

Although turbochargers can spin at great speed, up to nearly 100,000 rpm, they generally require little service during their normal life. Gaskets must be good, fasteners torqued, and the oil supply system open and functioning. Auxiliary controls such as boost control (by-pass valve) must operate correctly.

When removing the unit from the engine, clean before removal and cover any openings into the engine. Use extreme care during handling and repair to avoid the slightest nicking or bending of any part of the turbine or compressor blades. Blade damage would seriously reduce the unit's life. In some cases, it could cause the unit to literally destroy itself.

Inspect the turbine and compressor for nicks, bends, cracks, or clogs. Unit should spin freely and quietly. Check end play (axial play) with a dial indicator. Inspect boost control (by-pass valve) for proper operation. Follow all manufacturer's recomendations.

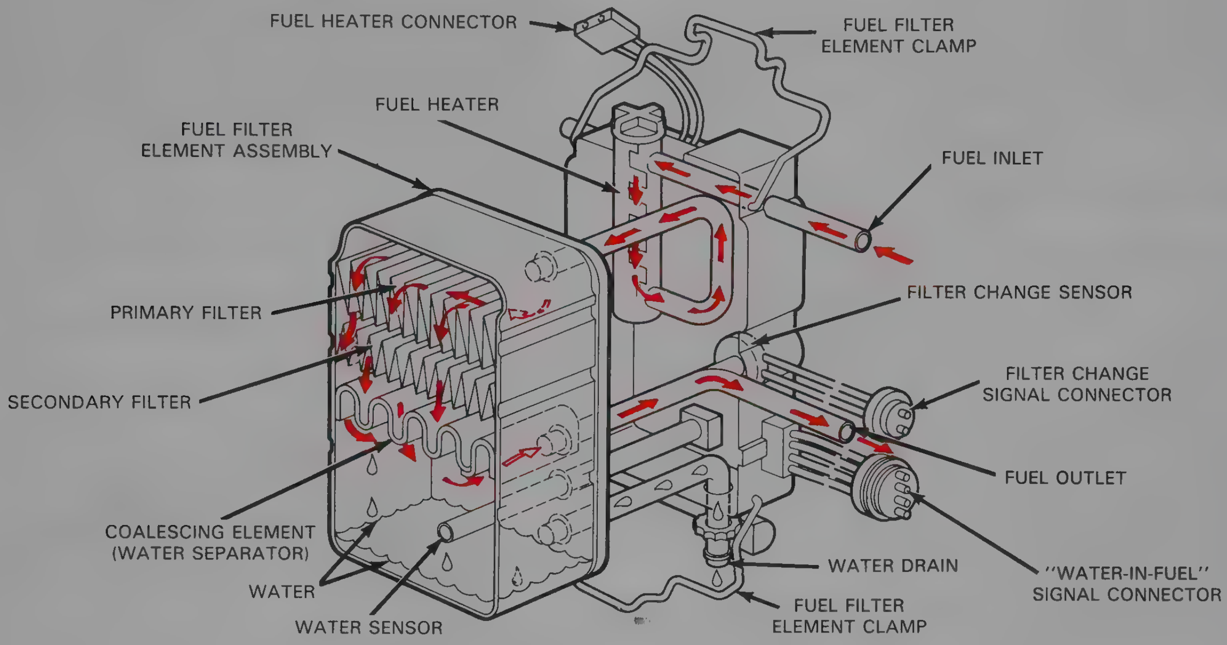

FUEL HEATER CONNECTOR
FUEL FILTER ELEMENT CLAMP
FUEL HEATER
FUEL FILTER ELEMENT ASSEMBLY
FUEL INLET
PRIMARY FILTER
FILTER CHANGE SENSOR
FILTER CHANGE SIGNAL CONNECTOR
SECONDARY FILTER
FUEL OUTLET
COALESCING ELEMENT (WATER SEPARATOR)
WATER DRAIN
"WATER-IN-FUEL" SIGNAL CONNECTOR
WATER
FUEL FILTER ELEMENT CLAMP
WATER SENSOR

Fig. 22-48. View of fuel filter with water sensor and sediment trap. (Chevrolet)

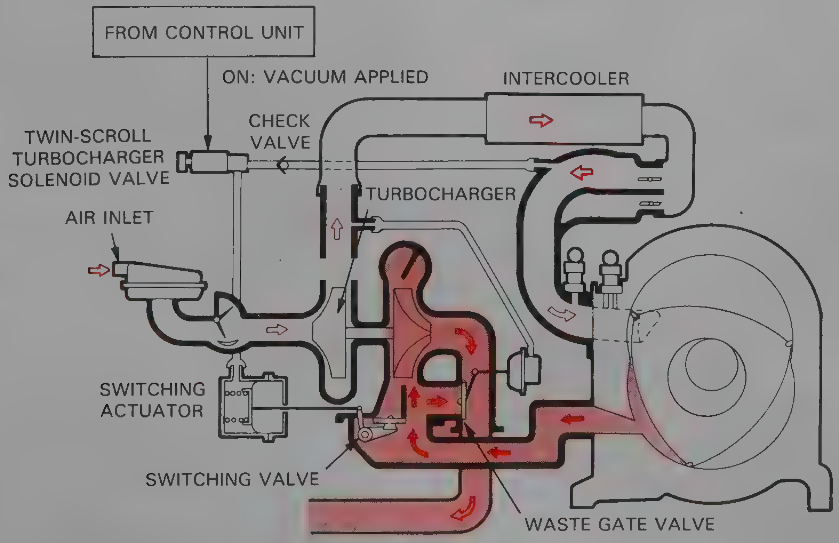

FROM CONTROL UNIT
ON: VACUUM APPLIED
INTERCOOLER
TWIN-SCROLL TURBOCHARGER SOLENOID VALVE
CHECK VALVE
TURBOCHARGER
AIR INLET
SWITCHING ACTUATOR
SWITCHING VALVE
WASTE GATE VALVE

Fig. 22-49. Schematic illustrating an exhaust-driven turbocharger. Note the use of an intercooler to drop the mixture temperature. Study the flow of the intake air and the exhaust gas. (Mazda)

SUPERCHARGERS

A supercharger is a belt-, chain-, or gear-driven pump that forces a dense mixture of air and fuel into the cylinders. By compressing the air-fuel mixture, the supercharger increases the engine's effective compression ratio, resulting in a higher engine power output. See Fig. 22-50.

The supercharger responds immediately when the accelerator is pressed. Boost pressure that is unused by the engine is routed through a by-pass valve and back into the supercharger. The by-pass valve is operated by a mechanical linkage or manifold vacuum.

The supercharger is generally located between the carburetor or fuel injection (throttle body) system and the intake manifold or intercooler. The intercooler unit cools the incoming air mixture, raising its density. This reduces engine knocking and improves driveability and performance.

SUPERCHARGER SERVICE

Supercharger service consists of making sure that the unit is clean, well oiled, and in proper condition. All hoses, clamps, and fittings must be in good condition. The air cleaner element should be checked for restrictions. Small vacuum leaks on the intake side of the supercharger will allow dust to enter the system. Excess dust can prematurely destroy the supercharger. Exhaust leaks tend to rob performance.

Superchargers are generally lubricated by the engine's oil system. Both standard and synthetic oils can be used in a supercharger system.

Defective supercharger units usually need to be replaced. Rebuilding is generally performed by the manufacturer. Follow ALL of the manufacturer's service procedures.

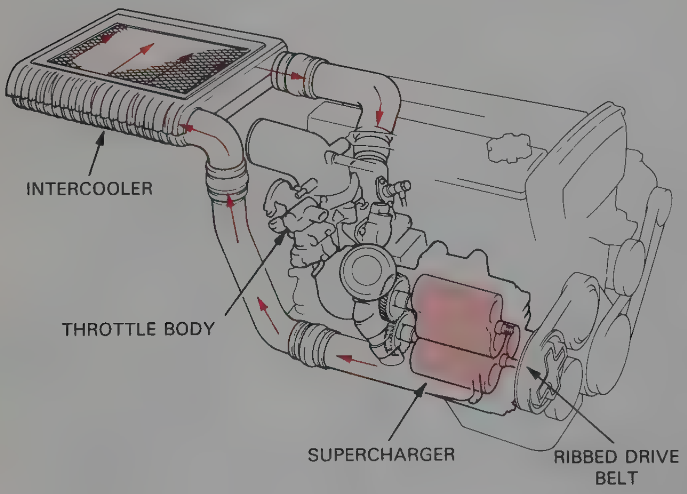


Fig. 22-50. One type of supercharger system. The aluminum rotors are turned by a ribbed drive belt, which is connected to the engine's crankshaft. Note the part relationships. This supercharger has an rpm range of approximately 10,000-15,000 rpms. (Toyota)

AIR CLEANERS

The three types of air filter elements commonly used today include the paper air cleaner element, the polyurethane element, and the linear flow filter element.

PAPER AIR CLEANER ELEMENT

The paper air cleaner element should be replaced at specified intervals. Between replacement periods, it may be cleaned by directing a stream of compressed air through the element in a direction opposite to regular airflow. See Fig. 22-51.

The paper element also may be cleaned by lightly tapping it on a flat surface. This will dislodge much of the dirt. Some dry type filters can be washed in water and mild detergent. This will usually be indicated on the filter itself or on an air cleaner housing decal. Refer to Fig. 22-52. Dry before using. Do not use excessive heat.

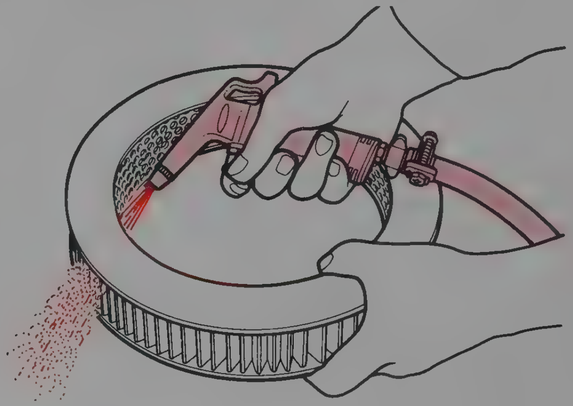


Fig. 22-51. Cleaning a paper filter element by blowing air through it from inside. Use a relatively soft stream of air and keep nozzle well back from filter surface. (Chrysler)

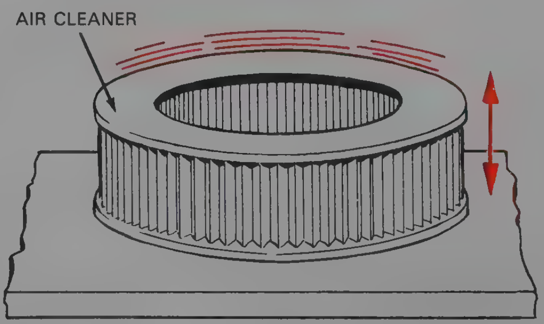


Fig. 22-52. Cleaning a paper filter element by tapping on a flat surface. Do not tap on one edge—strike with entire seal surface.

Before replacing, check the element against the light to make sure there are no ruptured spots. Check top and bottom gasket surfaces for injury. Install right side up where indicated. The element shown in Fig. 22-53 was badly damaged from careless handling.

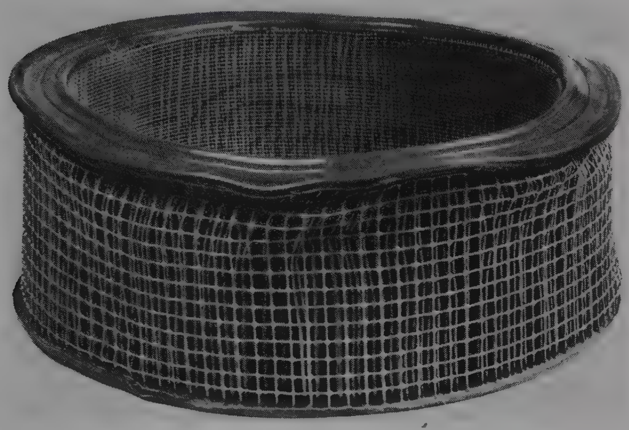


Fig. 22-53. Physical damage rendered this element unfit for further service. (Perfect Circle)

POLYURETHANE ELEMENT

Remove polyurethane element from the support screen. Wash it thoroughly in kerosene or some other mineral spirits. Squeeze out excess kerosene. Never twist, shake, slap, or wring because this may tear the element.

Place element in clean, light engine oil. Squeeze excess from the element and replace element on screen support.

Make sure the element is placed on the support to form a sound seal for both top and bottom contact edges. See Fig. 22-54.

On both the paper and polyurethane element filters, it is important that great care be exercised when removing the element. Do not let dirt fall into the carburetor or intake area. When practical, it is advisable to remove the entire filter as a unit. When filter is off, cover carburetor or fuel injection induction port with a clean cloth.

Be sure to clean the filter body and cover before replacing element. Make certain the carburetor-to-cleaner body gasket is in good shape and is in place. Tighten cover nut(s) securely. See Fig. 22-55.

Tools are available to measure the extent of filter clogging by checking the vacuum formed at a specific speed. The cleaner element in Fig. 22-56 is being checked by using a tachometer and a special vacuum gauge that is placed over the cover center hole. By following instructions, a good idea of element condition can be quickly determined.

When replacing the cleaner body, be sure it faces in

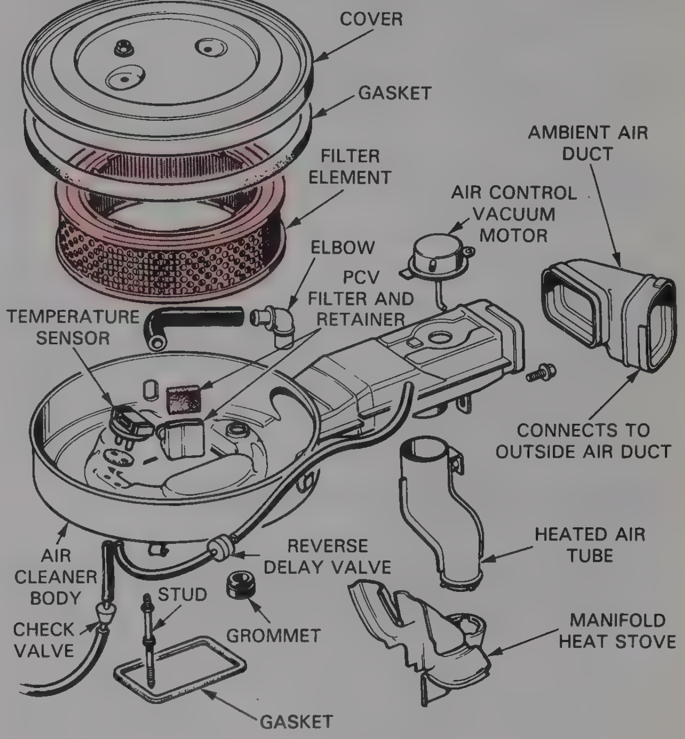

COVER
GASKET
AMBIENT AIR DUCT
FILTER ELEMENT
AIR CONTROL VACUUM MOTOR
ELBOW
PCV FILTER AND RETAINER
TEMPERATURE SENSOR
CONNECTS TO OUTSIDE AIR DUCT
AIR CLEANER BODY
REVERSE DELAY VALVE
HEATED AIR TUBE
STUD
CHECK VALVE
GROMMET
MANIFOLD HEAT STOVE
GASKET

Fig. 22-55. Typical air cleaner assembly. Both filter element and PCV filter must be kept clean. (AMC)

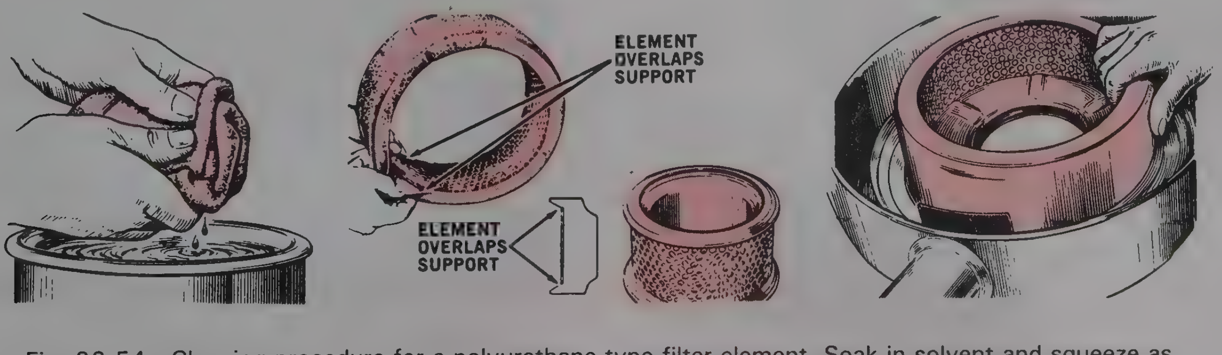

ELEMENT OVERLAPS SUPPORT
ELEMENT OVERLAPS SUPPORT

Fig. 22-54. Cleaning procedure for a polyurethane type filter element. Soak in solvent and squeeze as dry as possible. Soak in clean oil and squeeze out excess. Install element on support screen. Install in cleaner body. (Shell Oil Co.)

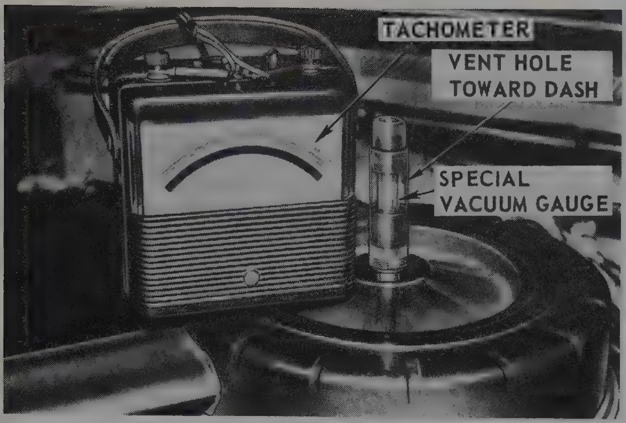


Fig. 22-56. Using a tachometer and a special vacuum gauge to check carburetor air cleaner element for clogging. (Chevrolet)

the correct direction. If a tang or a locating lug is present, see that the tang or lug engages properly.

CONTROLLED COMBUSTION SYSTEM FILTER ASSEMBLY

Fig. 22-55 shows the filter assembly as used in the Controlled Combustion System (CCS) emission control system. Temperature sensor activates the air control motor to operate a damper valve that can admit engine compartment air, hot air from manifold heat stove, or a combination. Check for correct operation.

LINEAR FLOW AIR FILTER ELEMENT

A linear flow air filter element is designed for use in a remotely mounted air cleaner housing, Fig. 22-57. Transverse engines and styling changes that limit clearance under the hood have made it necessary to relocate the air cleaner assembly on some vehicles.

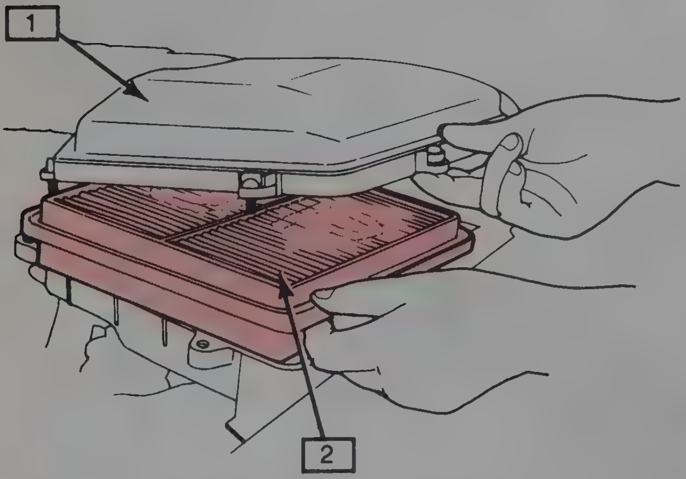


Fig. 22-57. Linear flow air filter element (2), being removed from its housing (1). Some are marked to indicate "up" or "airflow" direction. Be sure to install filter correctly. (Geo)

Linear flow filter elements are generally produced with an oil-wetted, resin-impregnated paper, which is folded in an accordion-like fashion. A gasket, molded around the filter element, serves as both an element seal and a housing seal.

Although the filter element can be cleaned, replacement is generally suggested.

FUEL MILEAGE CHECK

Many owners complain about poor fuel mileage without considering the factors that contribute to poor mileage. When owners ask, explain that mileage figures obtained in economy runs or on a long trip give false indications of the mileage to be expected from normal day-to-day driving. When there is a lot of stop-and-go driving, cold starting, or idling, mileage suffers. Always inform the owner about the gas robbing effect of rapid acceleration, prolonged idling, excessive speed, stop-and-go driving, low tire pressure, engine out of tune, and clogged air cleaners.

By using a measured amount of gas and driving the car (engine already warmed up) at a normal cruising speed over a level stretch, it is possible to come up with an accurate mile-per-gallon figure for AVERAGE cruising speeds. Make the test in two directions on a selected strip to allow for any wind or downgrade.

Fig. 22-58 illustrates the use of a flow-meter to determine approximate miles-per-gallon. This particular

Fig. 22-58. Using a flow-meter to determine approximate gas mileage. This setup is used in shop on a special test machine. (Bear)

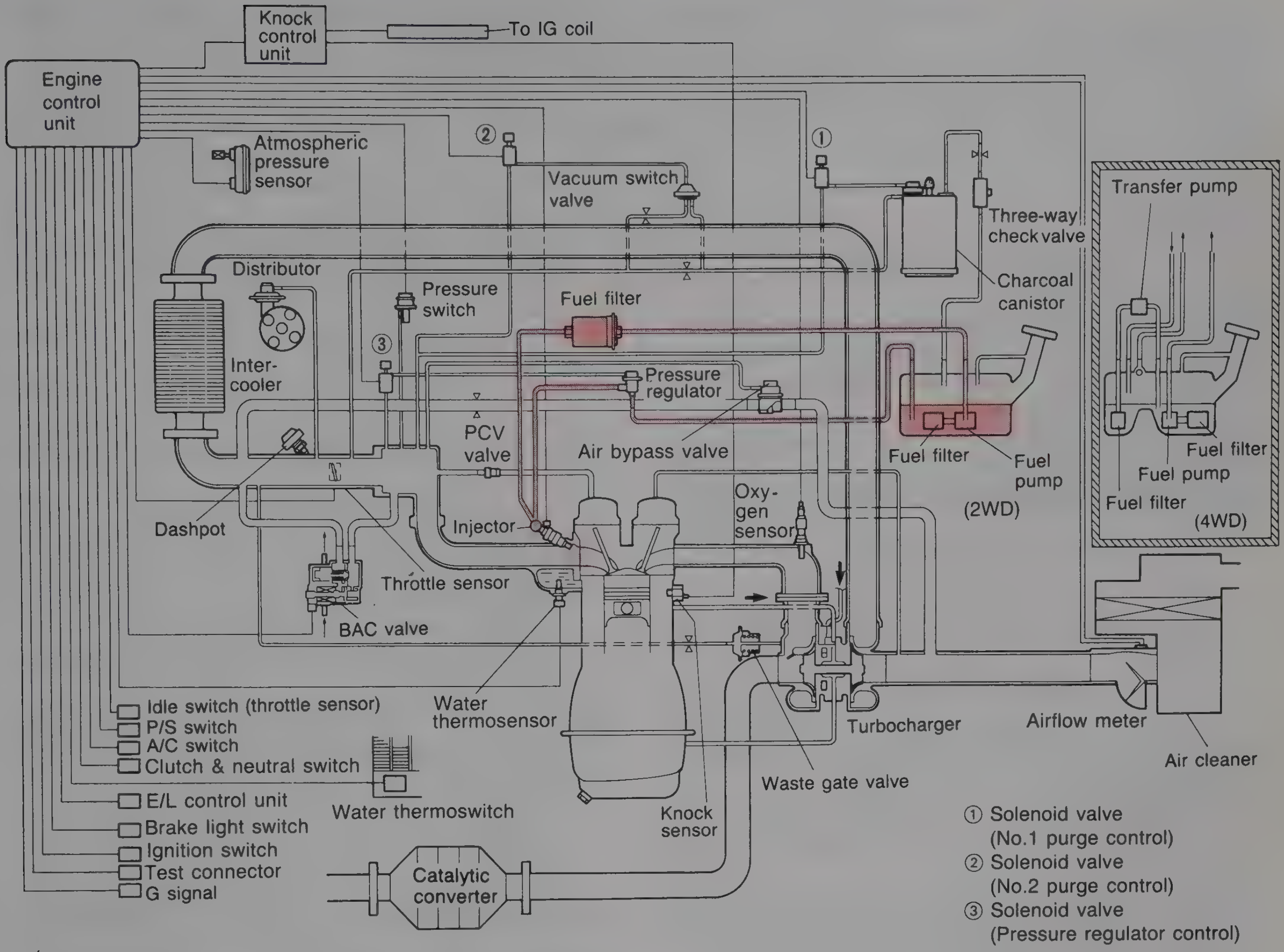

Knock control unit
To IG coil
Engine control unit
Atmospheric pressure sensor
②
①
Vacuum switch valve
Three-way check valve
Transfer pump
Charcoal canister
Distributor
Pressure switch
Fuel filter
③
Inter-cooler
Pressure regulator
PCV valve
Air bypass valve
Fuel filter
Fuel pump
(2WD)
Fuel filter
Fuel pump
Fuel filter
(4WD)
Dashpot
Injector
Oxy-gen sensor
Throttle sensor
BAC valve
Idle switch (throttle sensor)
P/S switch
A/C switch
Clutch & neutral switch
Water thermosensor
Turbocharger
Airflow meter
Air cleaner
Waste gate valve
E/L control unit
Water thermoswitch
Knock sensor
Brake light switch
Ignition switch
Test connector
G signal
Catalytic converter
① Solenoid valve (No.1 purge control)
② Solenoid valve (No.2 purge control)
③ Solenoid valve (Pressure regulator control)

Fig. 22-59. One type of gasoline fuel injection system that uses a turbocharger with an intercooler. Notice the various switches, sensors, etc., that are connected to the electronic control unit. (Mazda)

setup is part of a testing stand that will allow a number of engine tests to be made right in the shop. The car's rear wheels are placed on rollers.

SUMMARY

Fuel injection is becoming more widely used. It helps reduce emission levels and gives better gas mileage.

Two basic types of gasoline fuel injection are MECHANICAL and ELECTRONIC. The mechanical systems use an engine-driven injector pump. The electronic system uses an electric fuel pump to produce needed pressure.

Be careful to bleed fuel lines before taking off or loosening lines. Injector pumps require special tools and clean working conditions.

Two kinds of electronic fuel injection systems are the INTERMITTENT and CONTINUOUS flow systems.

The basic intermittent system consists of four parts - air induction, fuel delivery, electronic control unit (computer), and the electronic sensors. Injectors are opened electrically.

Injectors in the continuous system are always open. Air-fuel control is by airflow sensor unit that operates a fuel distributor.

Diesel engine injection systems use high injector pressures and inject directly into the combustion chamber. When working on injectors or pumps, use extreme care. Injector or line spray can be lethal. Keep system free of water.

Turbochargers use exhaust gases to spin a turbine, which drives a compressor. The compressor boosts air pressure in the intake manifold. Use care to avoid denting or nicking the turbine or compressor vanes. Vane damage could cause a destructive unbalanced condition. Superchargers are driven by belts, gears, or chains.

Change replaceable air cleaner elements at recommended intervals. Service others as required. When using air to clean filter element, use care to avoid damaging element.

Accurate fuel mileage estimates require careful testing. Inform owner that mileage can be greatly improved by good driving habits and proper maintenance.

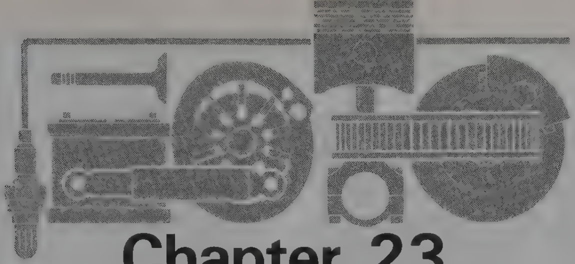
For a review of the gasoline injection system, study Fig. 22-59. Study the parts and trace through the various circuits.

KNOW THESE TERMS

Mechanical injection, Electronic injection, Intermittent injection, Continuous injection, Injector, Roller-vane pump, Fuel rail, Sensor, Cold start valve, Airflow sensor, Pressure regulator valve, Diesel injector, Injector pump, In-line injection pump, Rotary injection pump. Glow plug, Turbocharger, Thermal time switch, Electronic control, "Cracking" a fitting, Supercharger.

QUIZ - Chapter 22

1. Mechanical gasoline injection systems inject the fuel directly into the combustion chamber. True or False?
2. Mechanical injection systems use an ______ to produce the needed injector pressure.
3. Mechanical injection system injectors are opened by fuel pressure. True or False?
4. Two kinds of electronic fuel injection systems are the peolcd and the tootlk flow systems.
5. Why is it necessary to bleed the injection lines before loosening fittings or removing injectors?
6. Injectors in the continuous systems are opened by ______.
7. The intermittent system uses electrial operated injectors.
8. In the continuous flow system, air-fuel control is provided by an ______ sensor device.
9. The electronic control unit in the intermittent system is driven by the camshaft. True or [✓ False?]
10. List the four basic parts of the intermittent fuel injection system.
11. All gasoline injection systems use pressure exceeding 60 psi (413 kPa). True or False?
12. The continuous flow injector is opened:
    a. Electronically.
    b. By spring pressure.
    c. By fuel pressure.
    d. By vacuum.
13. The manifold pressure sensor responds to changes in manifold Intake Manifod parssure
14. Explain the use of the cold start valve.
15. Injectors always open in pairs. True or False?
16. When testing a diesel injector spray pattern, use a ______ around the fuel discharge.
17. Use a good grade of diesel fuel for all diesel injector testing. True or False?
18. The discharge from a diesel injector can penetrate deeply into flesh and, in addition to tissue destruction, can cause ______ ______.
19. Diesel injection pumps are one of two basic designs. Name them.
20. Diesel injectors inject fuel directly into the valve port area. True or False?
21. Diesel injectors are opened electrically. True or False?
22. Glow plugs are used to:
    a. Open the injectors.
    b. Heat the injectors.
    c. Assist in cold starting.
    d. Assist in hot starting.
23. Polyurethane elements can be washed and reused. True or False?
24. All paper air filter elements should be cleaned with hot water and mild detergent. True or False?
25. Superchargers can be driven by:
    a. Belts.
    b. Gears.
    c. Chains.
    d. All of the above.
26. Turbochargers boost intake pressure in the presure manifold.
27. Turbochargers are driven by:
    a. Intake airflow.
    b. A small electric motor.
    c. Exhaust gases.
    d. A V-belt.
28. Turbochargers spin very fast. In some designs, speeds can exceed 90,000 rpm. True or False?
29. Describe a special caution to observe when working on a turbocharger unit.
30. A paper air cleaner element can be cleaned by ______ on a flat surface or by ______ ______ with ______.
31. Name four things (not mechanical) that can cause poor fuel mileage.
32. When working on fuel systems, always keep an approved ______ ______ handy.



Chapter 23

IGNITION, CHARGING, AND STARTING SYSTEM SERVICE

After studying this chapter, you will be able to:

☐ Inspect, test, and repair electronic, computerized, and contact point ignition systems.
☐ Explain the difference between electronic ignition systems and computerized ignition systems.
☐ Describe the purpose of firing order information.
☐ Install and adjust contact points.
☐ Remove, test, and replace a distributor assembly.
☐ Adjust ignition timing.
☐ Clean, inspect, test, and replace spark plugs.
☐ Explain the use of an ignition scope.
☐ Install, test, and service a battery.
☐ Use jumper cables correctly.
☐ Service an alternator and a voltage regulator.
☐ Test, service, and repair a starting system.

The effectiveness of the ignition system, especially during cranking, depends considerably upon the battery. The battery must be fully charged. The posts must be clean. Battery cables and terminals must be in good condition and firmly attached.

The charging system should also be functioning correctly to produce specified system voltage during operation.

IGNITION SYSTEM PROBLEM DIAGNOSIS

The first step in ignition system problem diagnosis is to visually inspect the ignition components. Study the primary wires for signs of cracking, burning, and corrosion. All connections must be clean and tight. If the resistance in the primary circuit is excessive, the primary voltage may be reduced to a level that can seriously affect the secondary circuit available voltage. Check the coil and distributor cap for signs of flashover, burning, and corrosion. Coil polarity must be correct. Examine the secondary wires for evidence of swelling and deterioration. Wire ends should have good boots and must be inserted fully into the correct towers.

TROUBLESHOOTING A NO-START CONDITION—SPARK TEST

CAUTION! Electronic and computerized ignition systems can produce more than 40,000 volts. To reduce the risk of electrocution, always wear rubber gloves or use insulated pliers when performing spark tests on these systems.

If the engine will crank but not start, a spark test can be used to pinpoint the source of the problem. To perform this test, remove the coil secondary wire from the distributor cap. Hold the wire approximately 1/4 in. from the engine block (or other appropriate ground) and crank the engine. As the engine is cranked, an arc should jump between the wire and ground, Fig 23-1. If this does not occur, check the primary side of the ignition system. Components that may be at fault include the coil, the ignition switch, the electronic control unit, and the ignition resistor. Methods for testing these items will be covered later in this chapter.

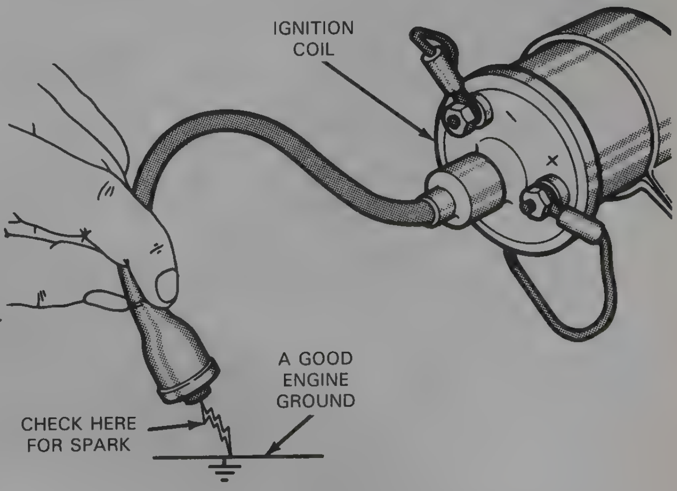


Fig. 23-1. When performing a spark test, hold secondary wire approxiamtely 1/4 in. from appropriate ground. (Chrysler)

If a spark is produced at the coil secondary wire, reconnect the wire and remove a secondary wire from a spark plug. Again, hold the wire 1/4 in. from the engine block and crank the engine. If there is no spark between the wire and ground, check the spark plug wire, distributor, and rotor. If a spark is produced, study the spark plugs for signs of fouling and other abnormalities. Remember, a no-start condition can also be caused by a fuel system problem.

TESTING, INSPECTING, ADJUSTING, AND REPLACING IGNITION SYSTEM COMPONENTS

When an individual part of the ignition system is suspected of being faulty, it should be inspected, tested, adjusted, repaired, or replaced. Always recheck the system following any adjustment or replacement to make certain the repaired circuit meets specifications.

IGNITION SWITCH

Occasionally an ignition switch will fail in service and must be replaced. If the switch is suspected of being faulty, it may be checked by connecting a voltmeter as shown in Fig. 23-2. Connect a jumper wire from the distributor terminal of the coil to ground. Switch should be ON, accessories and lights OFF.

If the reading is 0.3 volt or less, the ignition switch and the relay-to-switch wire are good. A reading in excess of 0.3 volt indicates either the wire or the switch (or both) is defective.

Jiggle the ignition key in and out. The voltmeter reading should remain constant. Turn the key off and on. The meter reading should return to the same level each time. Flex switch wire at both ends. The meter reading should remain steady.

When replacing an ignition switch, mark wires for correct replacement. DISCONNECT BATTERY GROUND CABLE TO PREVENT ACCIDENTAL SHORTS.

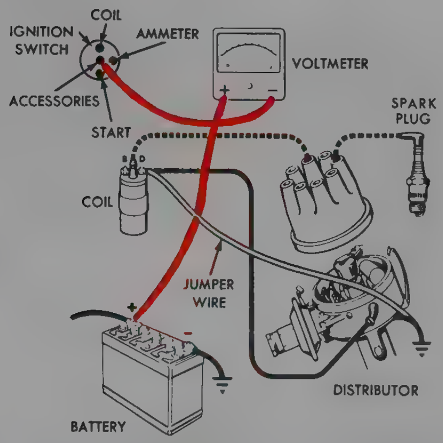

COIL
IGNITION SWITCH
AMMETER
VOLTMETER
ACCESSORIES
SPARK PLUG
START
COIL
JUMPER WIRE
DISTRIBUTOR
BATTERY

Fig. 23-2. Checking ignition switch with voltmeter. (Ford)

IGNITION RESISTOR

The ignition resistor (resistance wire or ballast type) must offer a specified amount of resistance to the battery-to-coil circuit.

One method of checking the wire type resistor is illustrated in Fig. 23-3. Connect the voltmeter as shown. Connect jumper wire. Turn ignition switch ON, accessories and lights OFF. Meter reading should not exceed 6.6 volts. If reading exceeds 6.6 volts, replace resistance wire. Be careful to install a correct service replacement. Recheck after replacement wire is installed.

An ohmmeter (measures resistance in ohms) is being used to check the resistance imparted by the ballast resistor in Fig. 23-4. DISCONNECT THE RESISTOR-TO-SWITCH WIRE TO PREVENT DAMAGE TO THE OHMMETER. Check reading against manufacturer's specifications. The ohmmeter can also be used to check the resistance wire type.

Do not make a test hookup that will connect the resistor directly across the battery as this will destroy the resistor.

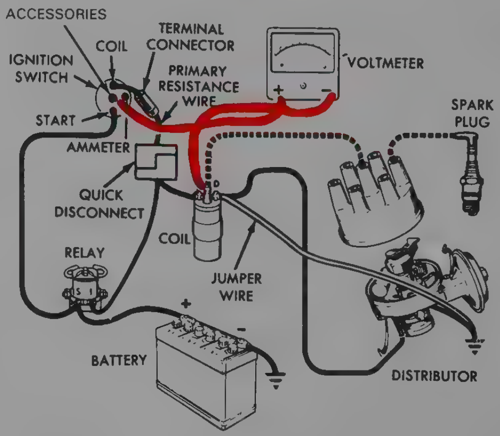

ACCESSORIES
TERMINAL CONNECTOR
COIL
IGNITION SWITCH
VOLTMETER
PRIMARY RESISTANCE WIRE
SPARK PLUG
START
AMMETER
QUICK DISCONNECT
COIL
RELAY
JUMPER WIRE
BATTERY
DISTRIBUTOR

Fig. 23-3. Checking resistance wire. Connect voltmeter and jumper wire. Turn ignition ON, lights OFF. Meter reading should not exceed 6.6 volts.

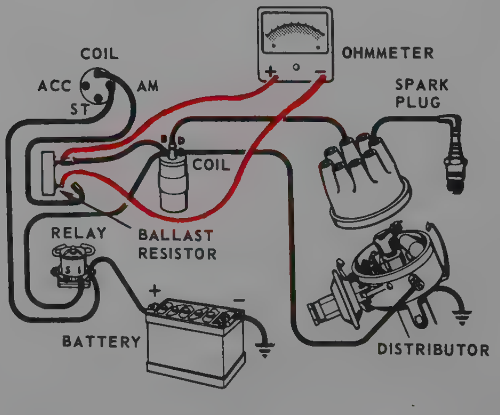

COIL
OHMMETER
ACC
AM
ST
SPARK PLUG
COIL
RELAY
BALLAST RESISTOR
BATTERY
DISTRIBUTOR

Fig. 23-4. Testing ballast resistor with ohmmeter.

TESTING THE IGNITION COIL

The ignition coil should be checked for available voltage. This test should be performed after the coil has reached operating temperature. Other checks include testing both primary and secondary circuit resistance and current draw during idle and when the engine is stopped.

These tests usually expose any internal shorts, grounds, opens, insulation breakdown, and loose or corroded connections. Use reliable test equipment and follow manufacturer's instructions.

Fig. 23-5 shows a coil being tested for both primary and secondary circuit resistance. Note the coil scope (oscilloscope) in the center of the instrument.

A typical contact controlled system waveform or pattern is pictured in A, Fig. 23-6. Electronic ignition system waveforms will vary somewhat, depending upon the system design. The available voltage can be determined by comparing waveform height against the kilovolt (one thousand volts) scale on the left side of the scope.

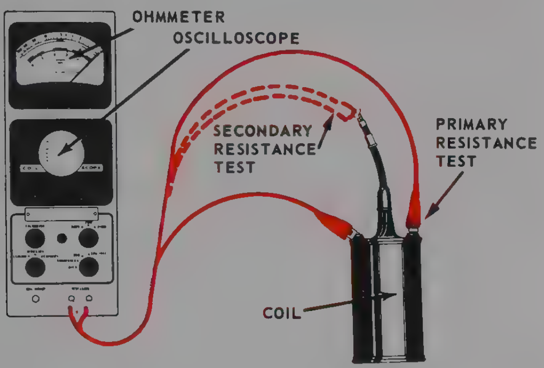

OHMMETER
OSCILLOSCOPE
SECONDARY RESISTANCE TEST
PRIMARY RESISTANCE TEST
COIL

Fig. 23-5. Coil secondary and primary resistance test hookups.

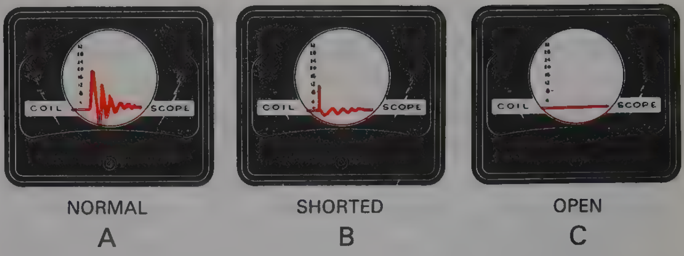

COIL
SCOPE
NORMAL
A
COIL
SCOPE
SHORTED
B
COIL
SCOPE
OPEN
C

Fig. 23-6. Waveforms or patterns on the oscilloscope indicate coil condition and, if poor, possible causes. (Sun Electric)

Item A, Fig. 23-6, shows a normal waveform pattern indicating a satisfactory coil. Waveform height is 20 kV (20,000 volts) or more. Item B shows the waveform caused by shorted primary windings, shorted secondary windings, grounded windings, or insulation breakdown. Item C indicates an open (broken) coil primary circuit.

Fig. 23-7 illustrates the use of an ohmmeter to check resistance in both an electronic ignition system coil and pickup coil. The parts being tested are: A—GM HEI V-8 distributor cap and coil combination; B—GM four and six cylinder separate coil; C—GM HEI system pickup coil.

Test point resistance indicators are: 1—Primary resistance (0-1 ohm). 2—Secondary (high scale, if both readings are infinite, replace coil). 3—Primary (0-1 ohm). 4—Secondary (replace coil if less than 6,000 or

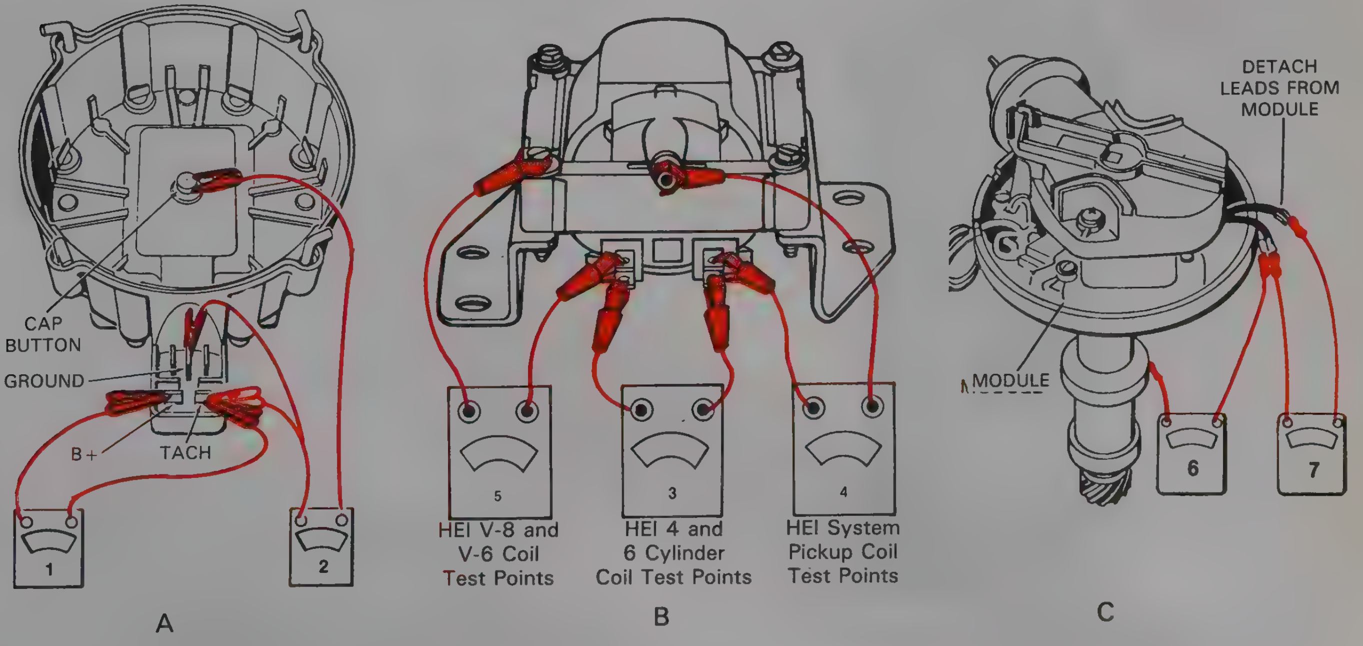

CAP BUTTON
GROUND
B+
TACH
1
2
A
5
HEI V-8 and V-6 Coil Test Points
3
HEI 4 and 6 Cylinder Coil Test Points
4
HEI System Pickup Coil Test Points
B
DETACH LEADS FROM MODULE
MODULE
6
7
C

Fig. 23-7. Using an ohmmeter to check for specified resistance values. (Champion)

more than 30,000 ohms). 5—Replace coil if resistance is less than infinite. 6—Replace pickup coil if resistance is less than infinite. 7—Should read between 500-1,500 ohms for this pickup coil. These values are for this system and will vary depending upon design. Always use specifications that pertain to exact unit being tested.

Remember that the coil is a vital part of the ignition system. When not in excellent condition, it should be replaced. Fig. 23-8 shows one type of coil.

CHECK COIL TOWER FOR CORROSION, FLASHOVER

Pull the high tension lead from the coil tower. Using a light, check the tower for signs of corrosion or burning. If corroded, clean with a round bristle brush or sandpaper on a pencil. Blow out with air.

Examine the tower for any sign of "flashover" (high voltage current leaving intended circuit or path and leaping down, around, or across directly to ground). Flashover can be caused by moisture or dirt on the tower surface, by a corroded tower, or by failing to shove the high tension wire fully into the tower.

Continued flashover burns the surface of the tower material, forming a path of carbon tracks. This path makes flashover even easier and the tower may be severely damaged. Note the carbon tracks (path) left by flashover on the coil tower in Fig. 23-9.

When flashover has cracked the tower or has left a burned path, replace the coil. When replacing a coil damaged by flashover, replace the old rubber nipple or boot. It probably has a carbon track path that will cause flashover with the new coil.

Prevent flashover by having a clean, tight tower wire connection, by having a good boot in place, and by keeping the tower and coil top free of dirt and moisture.

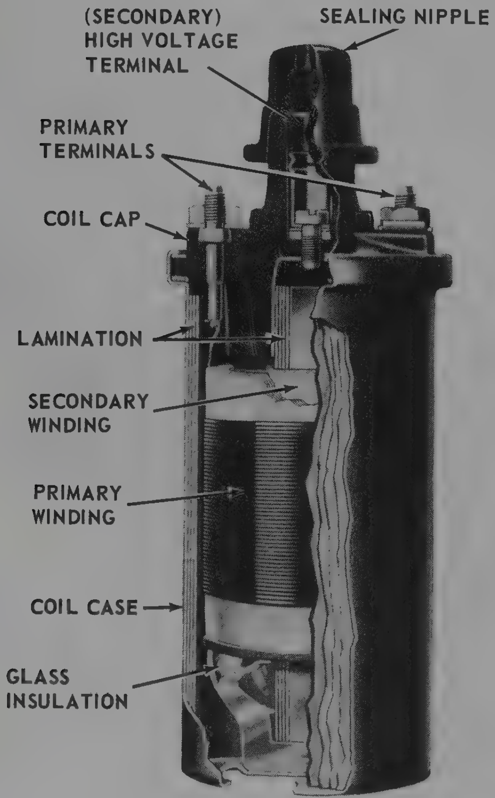


Fig. 23-8. Cutaway view of a typical ignition coil. (Chevrolet)

COIL POLARITY MUST BE CORRECT

The coil must be connected into the primary circuit so the coil polarity (+ *or* −) marks correspond to those of the battery. If the battery negative post is grounded, which is common practice, the negative terminal on the coil must be connected to the distributor. This will ground it through the contact points.

By connecting the coil in this fashion, the CENTER electrode of the spark plug will assume a NEGATIVE polarity.

The center electrode of the plug is always hotter than the side electrode. Since it takes less voltage to cause electrons to move from a hot to a cold surface, current flow must be from the hot center to the cooler side electrode. By giving the center electrode negative polarity, current flow will be as desired. See Fig. 23-10.

If the coil is connected so the plug center electrode is positive, up to 40 percent more voltage will be required to fire the plug. This can cause hard starting, missing, and poor overall performance. Always check for correct coil polarity.

CHECKING FOR CORRECT COIL POLARITY

Coil polarity is easily checked with a voltmeter. Ground the voltmeter positive lead. With the engine

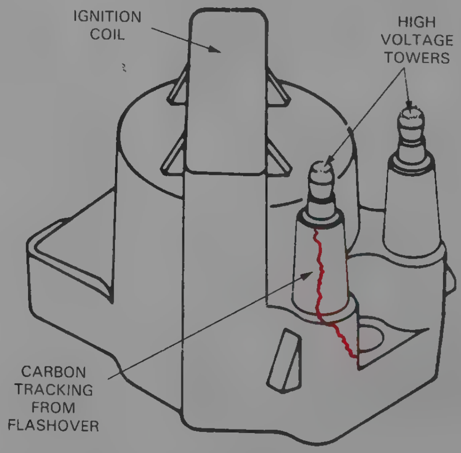
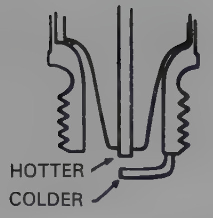
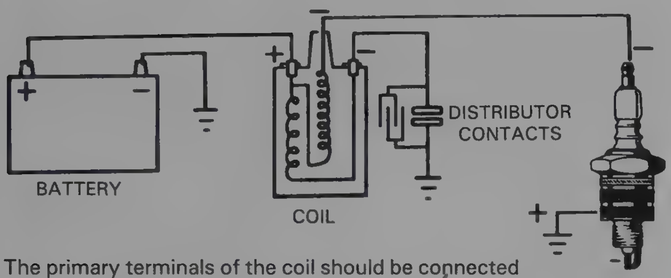


Fig. 23-9. Flashover has ruined this coil. Note carbon tracking path. (GM)



Electrons will move from a hot object to a cold object at a lower voltage.

A SPARK PLUG TIP



The primary terminals of the coil should be connected so that the polarity markings correspond to the polarity of the battery.

Correct spark plug polarity will result if the coil is properly connected.

B CORRECT COIL CONNECTIONS

Fig. 23-10. Coil must be connected to impart a negative polarity to spark plug center electrode. (Ignition Mfg's. Institute)

idling, quickly scratch the negative lead across one of the spark plug terminals. If the needle flickers up-scale, the polarity is correct. If it flickers down-scale, it is reversed. See Fig. 23-11.

When using an oscilloscope to test the ignition system, the waveform will be upside down if the coil polarity is reversed.

CHECKING SECONDARY WIRES

Many cars utilize special resistance type secondary wiring. In the event of ignition trouble, it is often wise to check each wire with an ohmmeter to determine if the resistance is within specified limits. This test will also show if there are breaks in the conductor, as well as poor conductor-to-terminal connections, Fig. 23-12.

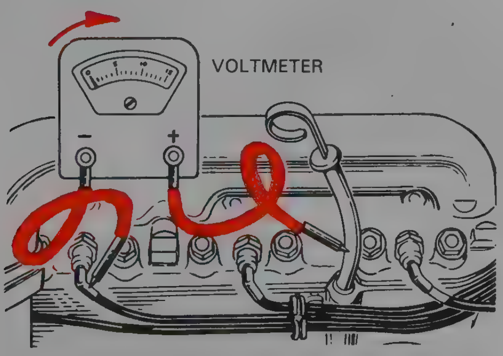


Fig. 23-11. Checking coil polarity with voltmeter. Needle swings up-scale (red arrow) if polarity is correct. (Automotive Electric Assn.)

Replace wires not within specifications. Use wires with specified resistance. Secondary wires can be made up as needed or secured as a factory set. Special gripping tools are available to aid in the removal of old wires and boots, Fig. 23-13.

Remove ONE old wire at a time and replace it with a new one. Use new boots. Make sure the wire is snapped firmly on the plug and is fully seated in the distributor tower. Continue, one wire at a time, until the set is replaced.

Remember that resistance wire is easily damaged. Grasp the boot (not the wire) and twist boot one-half turn to break seal, then pull. Never kink or jerk resistance wires. Avoid piercing insulation with test probes.

CAUTION! Some plug wires have the distributor cap electrodes permanently attached to the wire. These wires cannot be pulled until the positive locking terminal electrode is compressed from inside the cap. Fig. 23-14 shows how terminal is compressed to remove plug wire.

ARRANGE WIRES TO PREVENT CROSS FIRING

Arrange wires in the holders as recommended by the manufacturer. Coat inside of plug boots with silicone

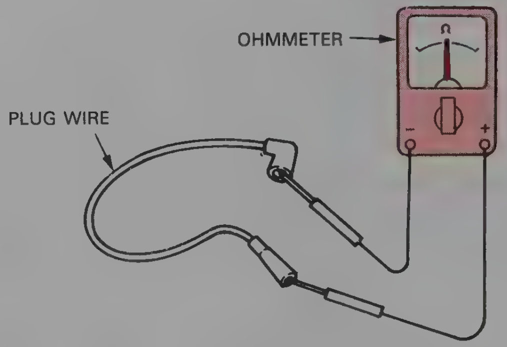


Fig. 23-12. Checking plug wire resistance with an ohmmeter. (Chrysler)

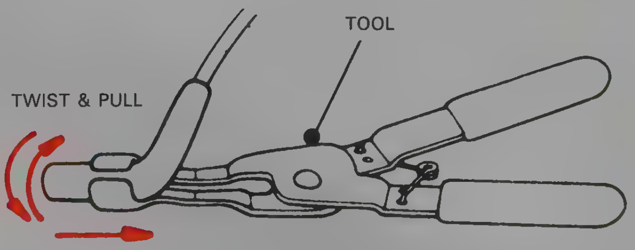


Fig. 23-13. Use a special tool like this to avoid damaging boot or wire during removal from spark plug. (Ford)

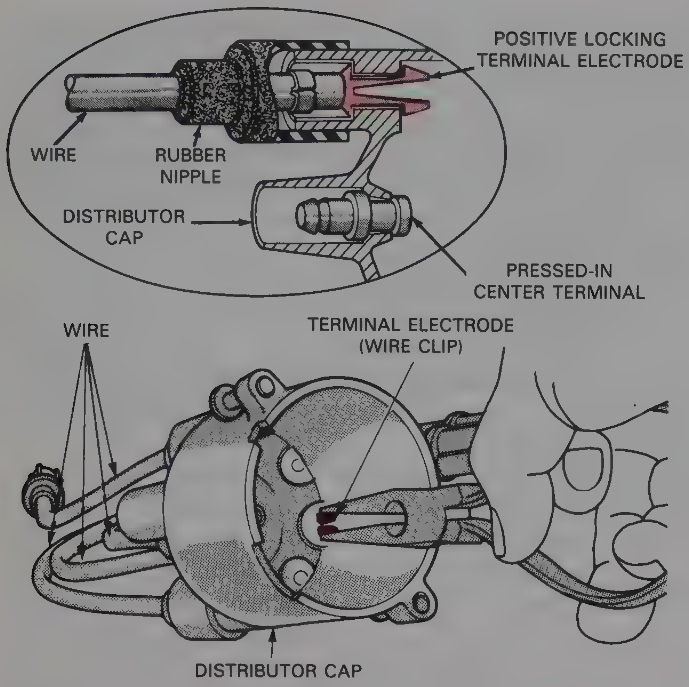

POSITIVE LOCKING TERMINAL ELECTRODE
WIRE
RUBBER NIPPLE
DISTRIBUTOR CAP
PRESSED-IN CENTER TERMINAL
WIRE
TERMINAL ELECTRODE (WIRE CLIP)
DISTRIBUTOR CAP

Fig. 23-14. Squeezing locking terminal electrode together so that plug wire terminal can be pulled out of cap. (Chrysler)

compound if so suggested.

If no directions are available, keep the following points in mind:

1. Avoid bunching wires together and running parallel. Keep them separated as far as practical.
2. Where two adjacent cylinders (plugs) on the same bank (side) fire in succession, keep these two plug wires separated by another wire. This will help prevent "cross firing" (one wire imparting enough voltage into an adjacent wire to cause it to fire its plug). Cross firing can cause serious mechanical damage to the engine. See Fig. 23-15.

   Improper wire routing can also cause short circuiting as well as significant radio interference.
3. Keep wires supported and away from heat and oily areas.
4. Make certain all wire ends are clean and firmly in place. All boots and wires must be in excellent condition.

FIRING ORDER

When replacing plug wires, be sure to maintain the correct firing order. This is the numerical order in which cylinders fire the fuel charge, starting with the number one cylinder.

Place the number one plug wire in the number one distributor tower. Insert the remaining wires in their correct firing order, going around the cap in the direction, clockwise or counterclockwise, that the distributor rotor turns. Pass through any wire supports and connect to the correct plugs.

On in-line engines (straight 4, 6, or 8-cylinder), the front cylinder (nearest timing chain cover) is the number one cylinder. On V-type engines, the number one cylinder will be at the front (timing chain end), but it can be either on the left or the right bank. See manufacturer's specifications.

Study the firing order (1-5-4-2-6-3-7-8) in Fig. 23-16. Note that the distributor rotor turns counterclockwise.

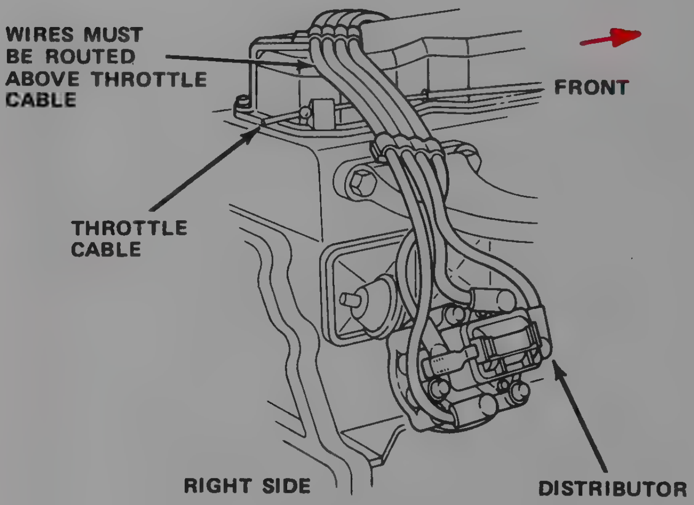

WIRES MUST BE ROUTED ABOVE THROTTLE CABLE
FRONT
THROTTLE CABLE
RIGHT SIDE
DISTRIBUTOR

Fig. 23-15. To avoid cross firing, radio interference, grounding, and damage, arrange spark plug wires as specified by manufacturer. (AMC)

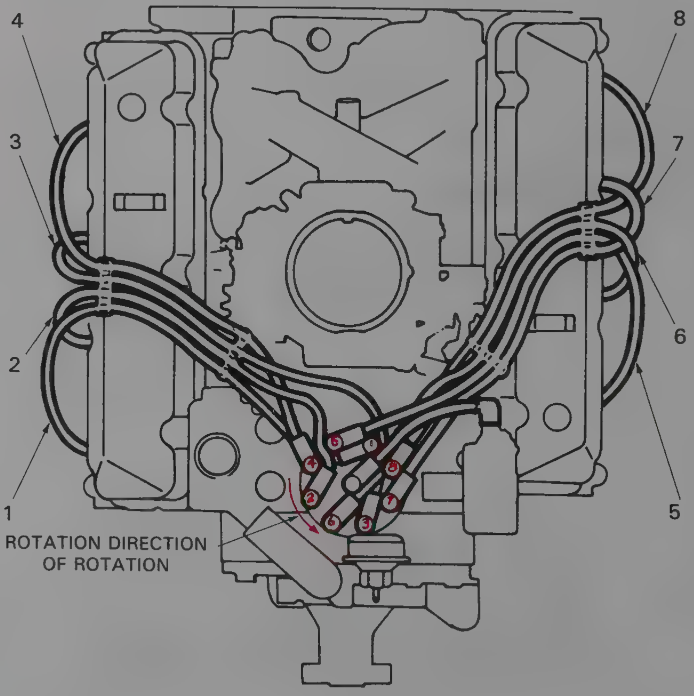

4
8
3
7
2
6
1
5
ROTATION DIRECTION OF ROTATION

Fig. 23-16. Firing order for one Ford V-8 engine. Note cylinder numbering arrangement. Arrange wires in proper order as specified. (Ford)

Note how wires (7 and 8) serving adjacent cylinders that fire in succession have been separated by another wire.

Number one tower is marked on some distributor caps. If it is not marked, be sure to mark before removing wires.

HOW TO FIND NUMBER ONE WIRE TOWER ON DISTRIBUTOR CAP

If manufacturer's shop manual is not available, remove distributor cap and spark plugs. Crank the engine until the number one piston is coming up on the compression stroke. Bump engine over a trifle at a time until the ignition timing mark is aligned with the pointer. Mark the outside of the distributor housing with chalk directly in line with the front of the rotor tip. Line up the distributor cap and snap it into place, making certain aligning tang is in place. In that the engine is now positioned to fire the number one cylinder, the rotor (chalk mark) will be aligned with the number one tower.

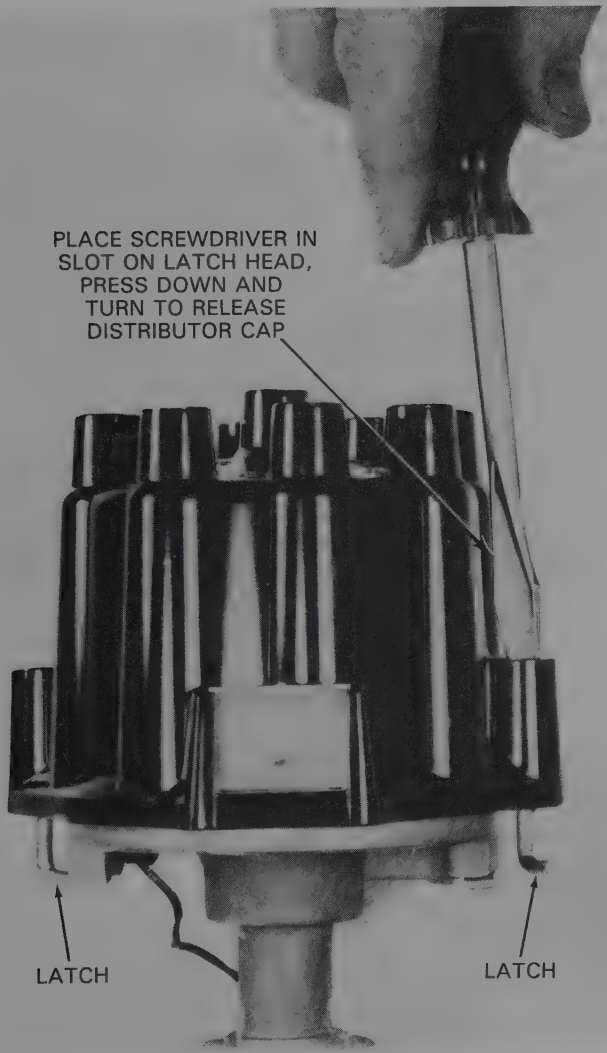

PLACE SCREWDRIVER IN SLOT ON LATCH HEAD, PRESS DOWN AND TURN TO RELEASE DISTRIBUTOR CAP
LATCH
LATCH

Fig. 23-17. Removing a distributor cap held in place with latch arms. One-quarter turn in either direction will loosen latch. Some caps are held in place with snap clips. Others are secured with hold-down screws. (Oldsmobile)

DISTRIBUTOR CAP INSPECTION

Pull each wire (one at a time) from the distributor cap wire towers. Inspect tower for signs of corrosion, burning, or flashover. Mild corrosion may be removed with a special wire brush or with sandpaper. Replace the cap if flashover has been present.

When replacing each wire, make sure the terminal is clean and is shoved into the tower to the full depth. Use new boots when replacing a cap.

Remove distributor cap by unsnapping spring arms or removing attaching screws. On window type caps, use a screwdriver to press latch arms down. When down, give a quarter turn either way to release, Fig. 23-17.

Inspect inside of distributor cap for signs of flashover. Check cap for cracking and central carbon button or rotor contact for burning or cracking, Figs. 23-18 and 23-19.

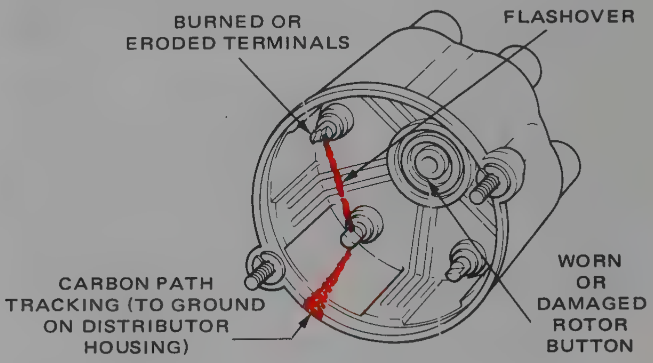

BURNED OR ERODED TERMINALS
FLASHOVER
CARBON PATH TRACKING (TO GROUND ON DISTRIBUTOR HOUSING)
WORN OR DAMAGED ROTOR BUTTON

Fig. 23-18. Cap cracks, broken towers, or carbon tracking from flashover can cause serious ignition troubles. (Jeep)

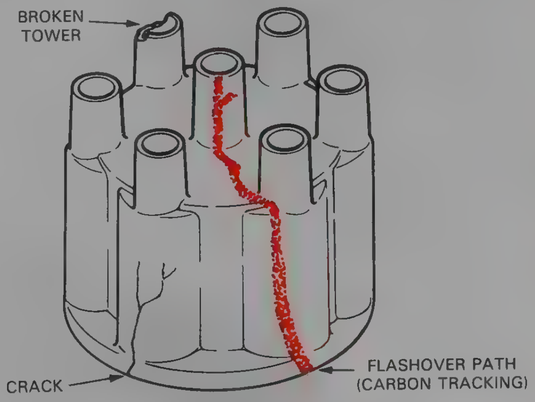

BROKEN TOWER
CRACK
FLASHOVER PATH (CARBON TRACKING)

Fig. 23-19. Carbon tracking, caused by flashover from distributor central coil terminal, over cap and down one side to ground on distributor housing. Note other cap damage also. (Jeep)

If terminal posts are burned or grooved, replace cap. Mild scaling, caused by sparks leaping from rotor tip to terminal post, can be scratched off with a sharp knife blade. When replacing cap, it is wise to replace rotor.

A cap that is greasy or dirty on the outside or is dusted on the inside with flecks of material from the rotor tip and terminal posts may be cleaned. Remove (mark number one wire tower and know firing order) and wash the cap in warm water and mild detergent. Use a clean cloth and soft fiber bristle brush. Dry thoroughly and replace. Make sure rotor is in place and the cap aligning lug is in the distributor housing cutout.

TESTING DISTRIBUTOR CAP

High voltage testing equipment should be used to check the dielectric (insulation quality) property of the cap. The equipment will enable you to spot carbon tracking, cracking, and other problems.

ROTOR

Inspect the rotor for excessive burning on the tip. Check the contact spring and resistance rod (if used). See Fig. 23-20. This shows a rotor in good condition. Fig. 23-21 shows the same type rotor with the tip completely burned off. Whenever the distributor cap is replaced, replace the rotor.

Rotors, such as the one illustrated in Fig. 23-20, are removed by grasping and pulling straight up. Another type distributor uses a rotor that is held in place with screws. When installing a rotor, make certain it is aligned with the flat on the distributor shaft and that it is pressed down fully. A rotor that is carelessly installed can either damage the distributor cap, itself, or both.

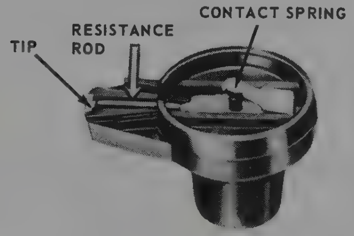


Fig. 23-20. Check rotor for burning, cracking, broken spring, etc.

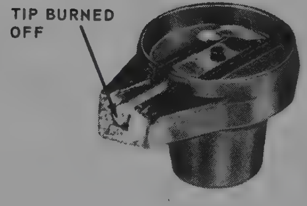


Fig. 23-21. Rotor with tip burned off.

When replacing some electronic ignition system rotors, the manufacturer recommends applying a silicone compound to the end of the rotor tip. This helps to suppress radio interference.

Apply silicone to the rotor tip ONLY when specified by manufacturer. Use recommended compound.

ELECTRONIC IGNITION DISTRIBUTOR SERVICE

Electronic ignition systems use a crankshaft position sensor (magnetic pickup, Hall effect pickup, or optical sensor) and an ignition control unit to operate the ignition coil. Although the components of the electronic ignition distributor are relatively trouble free, problems can still develop within the system.

If a malfunction occurs, all the components should be visually inspected for damage. Study the wires for breaks and worn insulation. The trigger wheel in magnetic and Hall effect pickup assemblies should be checked for broken teeth (blades), Fig. 23-22. Pickup coils should be inspected for external damage. If an optical distributor system is used, make sure that the slots in the rotor disk are unobstructed.

An ohmmeter is commonly used to check the condition of Hall effect pickups and magnetic pickup coils. If the pickup's resistance is not within the manufacturer's specifications, the unit must be replaced.

Methods for checking magnetic pickups, Hall effect pickups, and optical sensors vary among manufacturers. Always consult an appropriate service manual before testing these units.

BREAKER POINT SERVICE

Separate the breaker points (switch off) and check point condition. A dull, slate gray color is normal. Burned, badly eroded, excessive pitting, or metal transfer will require replacing the points, Fig. 23-23.

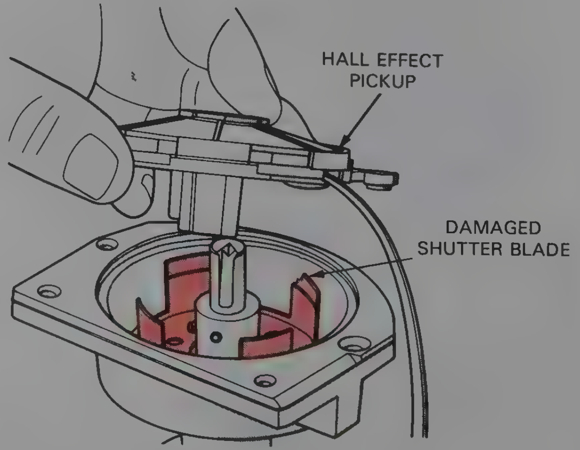


Fig. 23-22. Crankshaft position sensors should be inspected for damage. Note broken shutter blade on this Hall effect assembly. (Chrysler)

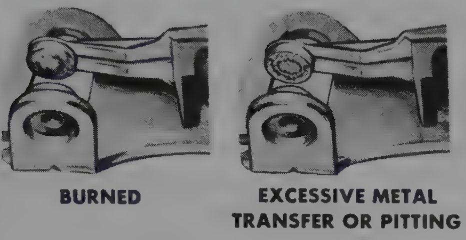


Fig. 23-23. These points must be replaced. (Ford)

If the points are the normal color and if wear is not excessive, they may be cleaned with a CLEAN, fine-cut point file. Do not attempt to file away all marks—a light dressing will suffice. Do not file the points at an angle or in any way alter the shape. Some mechanics prefer to use a thin point stone. NEVER USE EMERY CLOTH TO CLEAN POINTS.

When finished filing, pull a clean piece of smooth paper through the points to remove any metal particles. Dampening the paper with a suitable, oil free, quick dry cleaner will help remove traces of oil.

Check the movable breaker arm rubbing block for wear, Fig. 23-24.

Rapid rubbing block wear can be caused by a rough cam surface, excessive spring pressure, or by lack of lubricant. Cam surface should be smooth for proper rubbing block life. See Fig. 23-25.

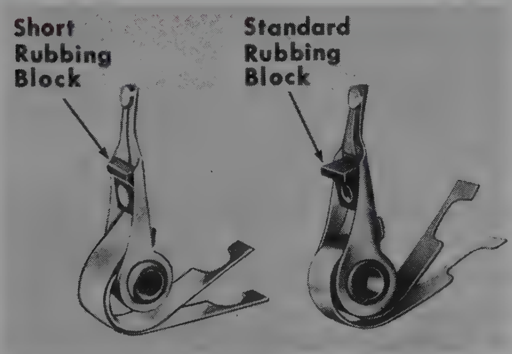


Fig. 23-24. Check rubbing block for wear.

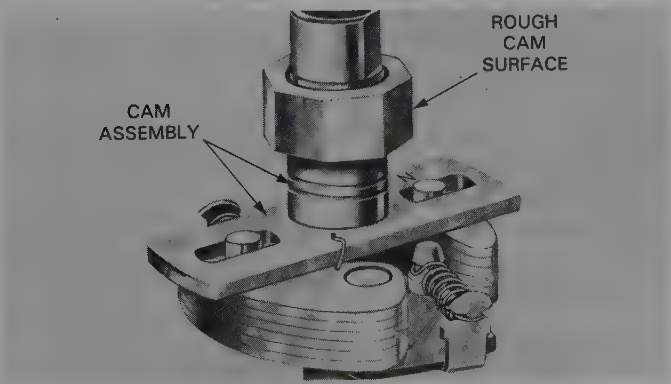


Fig. 23-25. Rough cam surface will cause rapid wear of rubbing block. (GM)

BREAKER POINT INSTALLATION

Before removing the old points, stuff clean rags in any hole around the breaker plate. Block any hole that is large enough to allow a small screw or washer to drop through.

Note location and positioning of the primary lead wire and condenser terminals before removing the old points.

Remove used points. Clean point mounting area and install new points.

POINT GAP

Point gap (the amount of opening between points when fully opened by cam lobe) is critical and must be closely adjusted. When the gap is too small, the points will arc and burn. Excessive gap will reduce the dwell angle (number of degrees of rotation of ignition distributor shaft during which contact points are closed) and cause missing at high speed.

Turn the distributor cam until the breaker arm rubbing block is on the highest tip of one of the lobes. Look at Fig. 23-26.

Loosen the locking screw A, Fig. 23-27, just enough to allow the breaker support plate to be moved by turn-

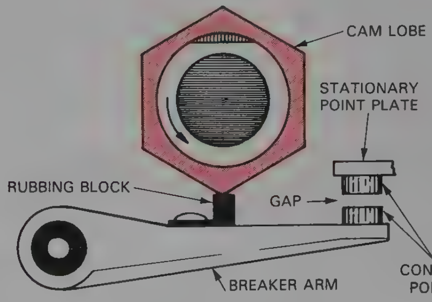


Fig. 23-26. Turn distributor cam until breaker arm rubbing block bears against highest portion of cam lobe.

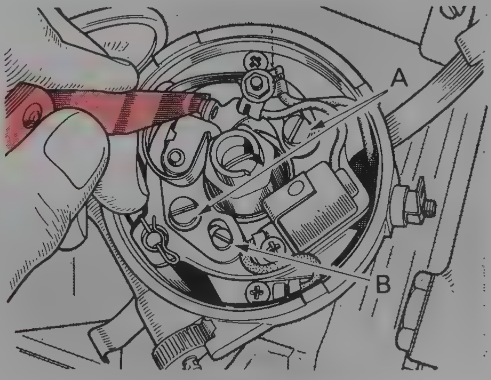


Fig. 23-27. Checking initial (new points) contact point gap setting with a feeler gauge. If the points have been in service, a feeler gauge will not provide the necessary accuracy. To adjust, loosen A and turn B as required. (Jaguar)

ing screw B and turn as required to open the points to the specified gap. This gap may be INITIALLY SET with a feeler gauge.

The points in Fig. 23-28 are easily gapped by turning the adjusting screw the specified distance—usually one-half turn counterclockwise past the "points just opening" point.

Used points, other than the type shown in Fig. 23-28, cannot be set (gapped) accurately by using either a wire or flat feeler gauge. The gauge measures between the high spots. The actual opening distance can be much greater, Fig. 23-29.

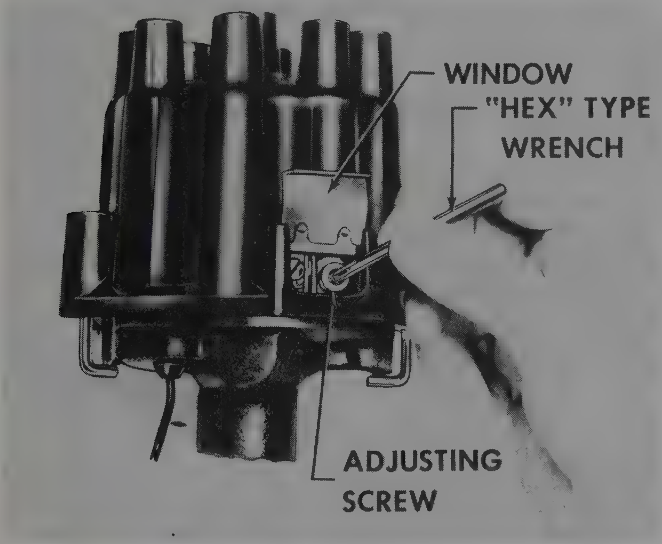


Fig. 23-28. This set of points is easily gapped by turning an adjusting screw with an Allen wrench. Close window when finished. (GM)

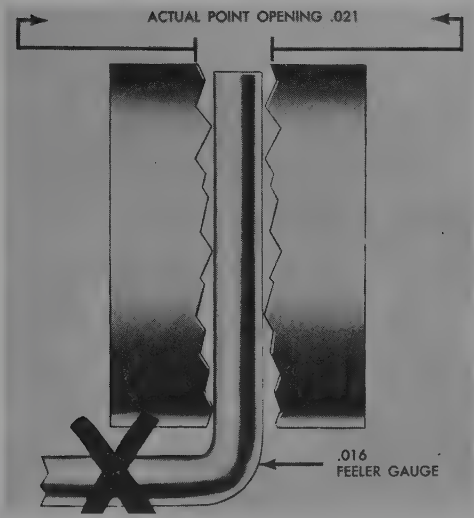


Fig. 23-29. Gapping used points with a feeler gauge will give false settings. Note how a .016 in. (0.41mm) feeler is snug yet actual opening is .021 in. (0.53 mm).

BREAKER ARM TENSION

The breaker arm tension must be correct to provide proper operation and wear. If the pressure is high, the rubbing block will wear down rapidly causing the point gap to narrow. This will retard the timing and increase the dwell angle. Low tension will cause the points to "float" or "bounce" at high rpm.

Use an accurate ounce (gram) scale to check breaker arm tension. Rubbing block should be between the cam lobes (points closed). Hook the scale on the end of the breaker arm right against the contact point edge. Pull outward at right angles to the arm. Read the tension at the instant the points separate, Fig. 23-30.

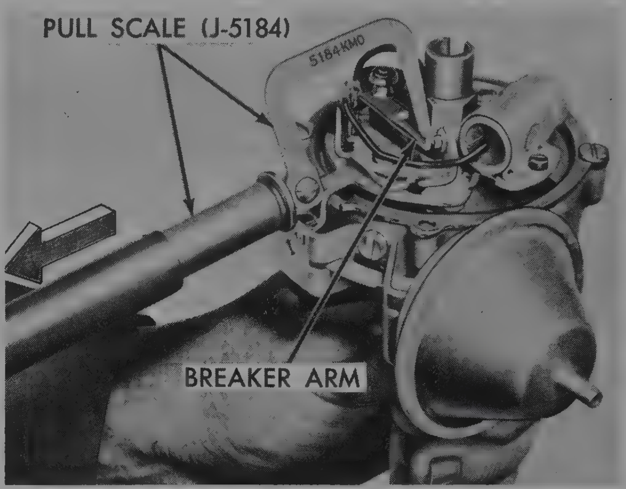


Fig. 23-30. Using a pull scale to measure breaker arm spring tension. Note how scale is held at right angles to arm. (G.M.C.)

IGNITION CONDENSER

Common practice is to change the condenser when the points are replaced. If the condenser is not to be changed, it should be checked for capacity, resistance, and leakage. A new condenser should also be checked. One setup incorporates the condenser as an integral part of the point set.

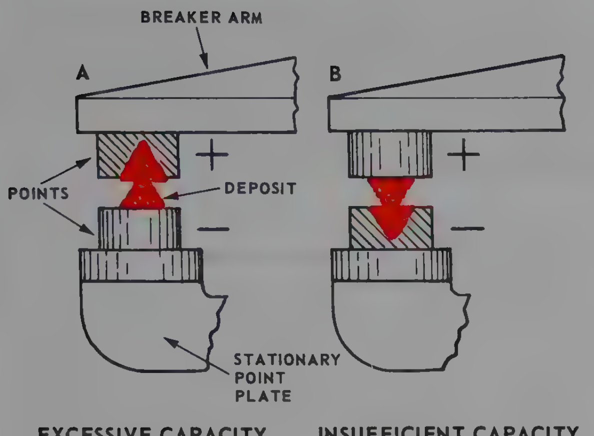
Attach new condenser making sure the wire is firmly affixed and free of any moving parts.

A condenser that is not functioning properly can allow heavy arcing at the points. If of the wrong capacity, it can cause metal to be removed from one point and deposited on another, Fig. 23-31.

Excessive metal transfer can also be caused by frequent high speed operation, wrong dwell angle, or voltage regulator setting too high.

LUBRICATE DISTRIBUTOR CAM

When new points are installed, the distributor cam should be cleaned and given a thin coat of high



EXCESSIVE CAPACITY CONDENSER

INSUFFICIENT CAPACITY CONDENSER

Fig. 23-31. A condenser with incorrect capacity can cause metal transfer from one point to other. A—Excessive capacity. B—Insufficient capacity.

temperature grease. DO NOT USE ENGINE OIL OR LOW TEMPERATURE GREASE. THEY WILL BE THROWN OUTWARD INTO THE POINTS.

Some point sets include cam lubricant in a small capsule.

SETTING DWELL ANGLE

If the distributor is off the car and a distributor tester is available, set up the distributor. Set specified dwell (use dwell meter) by carefully adjusting the points.

If the distributor is on the engine, attach a dwell meter. While idling the engine, check the dwell. Adjust point gap as required. If point adjustment fails to give the specified dwell, the cam may be worn. The points may also be wrong for the car.

Run the engine up to around 1500 rpm. The dwell should not vary more than 3 deg. Variations in excess of this indicate a faulty distributor. Fig. 23-32 illustrates how a tach-dwell (combination tachometer and dwell meter) is set up to check dwell.

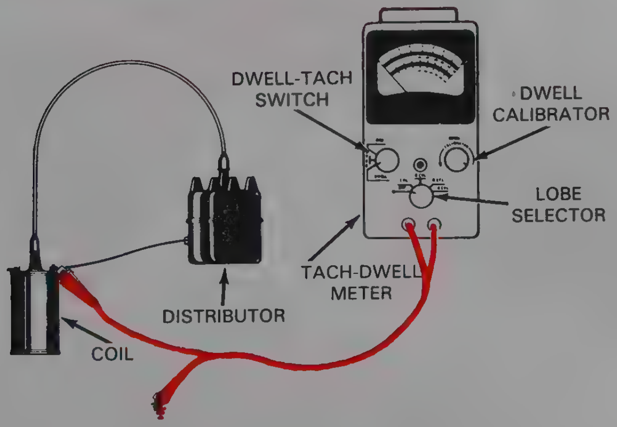


Fig. 23-32. Checking dwell angle with a tach-dwell meter. The diagram shows NEGATIVE ground connections. Reverse leads for POSITIVE ground. (Sun Electric)

Always follow test instrument manufacturer's directions.

DWELL—ELECTRONIC IGNITION

The dwell period is controlled electronically in the electronic ignition system. There are no mechanical adjustments required.

Dwell is automatically increased as engine rpm rises and decreases with a speed reduction. This provides the required spark intensity within a controlled dwell period that is consistent with coil performance, temperature tolerance, and service life.

ELECTRONIC IGNITION CONTROL MODULE SERVICE

The electronic ignition control module is generally tested with a voltmeter or an ohmmeter. Some ignition control modules, however, must be checked with special equipment. Testing procedures vary among manufacturers. Always consult an appropriate service manual before testing the module. Improper equipment or incorrect connections can destroy the unit.

To aid in locating intermittent problems, many technicians heat the ignition control module. This can be done with a heat lamp or a heat gun. Heat the unit only until it reaches its normal operating temperature. Excessive heat can destroy the ignition module's internal components. Always make certain that the module is mounted tightly. A tight connection helps the ignition module dissipate heat, which can cause serious damage to the unit's internal components.

DISTRIBUTOR ADVANCE MECHANISMS

To provide the proper spark advance or retard to fit all speeds, throttle openings, and engine loading, some distributors are equipped with both a vacuum advance and a centrifugal advance unit. Most distributors, however, have no such advance control units in that these functions are controlled electronically.

The vacuum and centrifugal units may stick, wear out, or become defective in other ways.

Fig. 23-33 illustrates one type of centrifugal advance. A vacuum advance unit is also shown. A typical single diaphragm vacuum advance mechanism is pictured in Fig. 23-34. Note how diaphragm lever actuates movable magnetic pickup plate.

QUICK TESTING CENTRIFUGAL ADVANCE

If the distributor is on the car, disconnect the vacuum line to the vacuum advance. Run the engine slowly from an idle up to around 4000 rpm. Use a timing

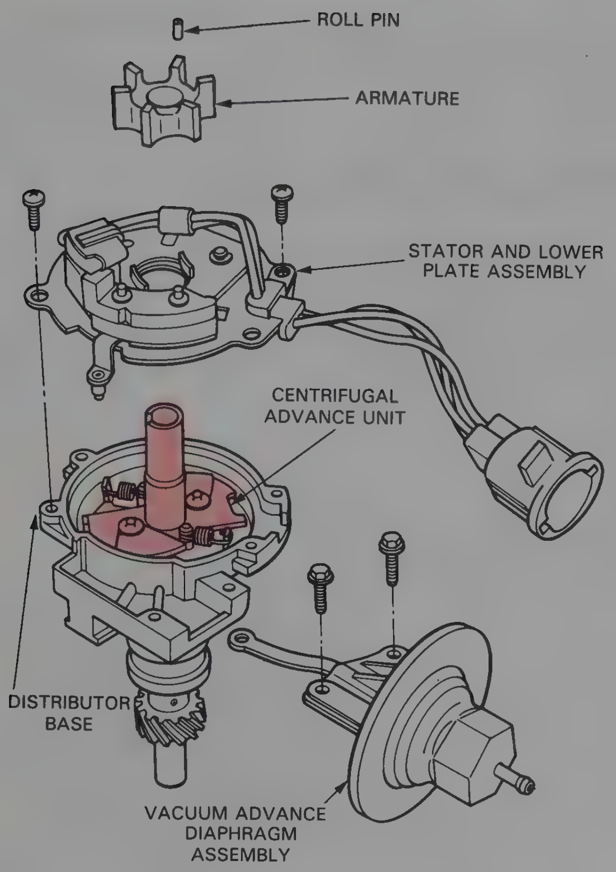

ROLL PIN
ARMATURE
STATOR AND LOWER PLATE ASSEMBLY
CENTRIFUGAL ADVANCE UNIT
DISTRIBUTOR BASE
VACUUM ADVANCE DIAPHRAGM ASSEMBLY

Fig. 23-33. One type of centrifugal advance assembly. (Ford)

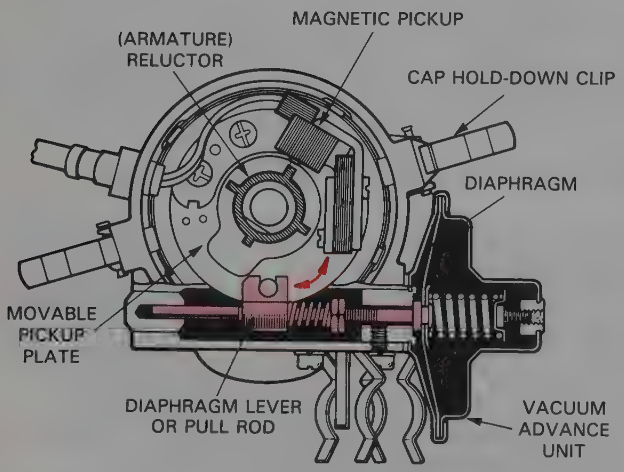

MAGNETIC PICKUP
(ARMATURE) RELUCTOR
CAP HOLD-DOWN CLIP
DIAPHRAGM
MOVABLE PICKUP PLATE
DIAPHRAGM LEVER OR PULL ROD
VACUUM ADVANCE UNIT

Fig. 23-34. Cutaway showing construction of a single diaphragm vacuum advance unit. (Toyota)

light to watch the timing mark. It should advance smoothly against the direction of engine rotation. When the action is jerky, stop the engine. Remove distributor cap and twist the rotor in the direction of rotation. When the rotor is released, it should snap back to the original position. A slow return indicates a gummy or corroded advance unit. Clean and oil. A loose rattle-type condition indicates broken or stretched return springs. Replace parts as needed. Distributor should then be checked out, using distributor tester.

QUICK TESTING VACUUM ADVANCE

Disconnect vacuum advance line. Connect a power timing light. Start engine and run at a steady 1200 rpm. Note position of the timing mark in relation to the pointer. Connect vacuum advance line. When line is connected, the timing mark should immediately move against the direction of engine rotation (advance). If nonoperative, remove distributor and test on distributor machine. In addition to the vacuum unit, check for a sticky breaker plate.

A hand-operated vacuum pump can be used to apply a controlled vacuum. One is shown in Fig. 23-35. When applying vacuum, check vacuum advance operation for function and smoothness. Vacuum advance diaphragm should hold in position until vacuum is released. If any sign of leakage is observed, replace unit.

TEST TOOLS FOR CHECKING DISTRIBUTOR ON CAR

Test tools are available for checking the degree of advance provided by the vacuum and centrifugal units. If checks indicate repairs are needed, the distributor should be removed, repaired, and checked on a distributor tester.

ADJUSTING CENTRIFUGAL ADVANCE UNIT

The centrifugal advance unit should be clean and lightly oiled.

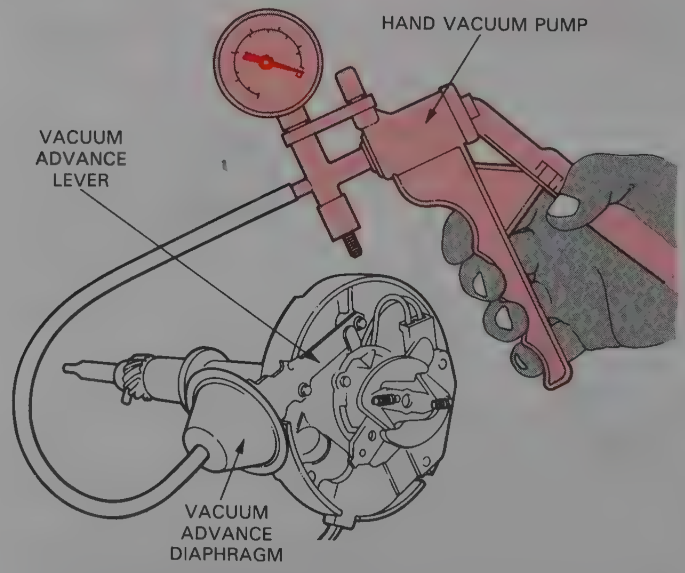

HAND VACUUM PUMP
VACUUM ADVANCE LEVER
VACUUM ADVANCE DIAPHRAGM

Fig. 23-35. Using a hand-operated vacuum pump to test distributor vacuum advance operation. (GM)

Some units provide adjustable (bendable) spring anchor tabs or post to vary spring tension. This lets you bring the advance curve (relation between degree of advance and engine rpm plotted from idle to high rpm) within specifications. Other units require spring alteration or replacement.

Fig. 23-36 illustrates a typical centrifugal advance mechanism. Note the anchor tabs. When adjustment or spring replacement has been completed, unit must be tested for proper operation. Follow manufacturer's specifications.

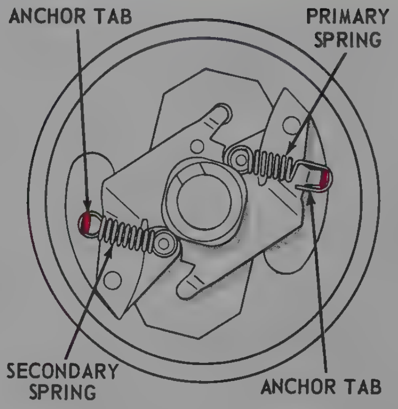

ANCHOR TAB
PRIMARY SPRING
SECONDARY SPRING
ANCHOR TAB

Fig. 23-36. Typical distributor centrifugal advance unit. Note spring anchor tabs. These may be bent to vary spring tension as needed to adjust advance characteristics. (Toyota)

ADJUSTING VACUUM ADVANCE

Some vacuum advance units are nonadjustable and must be replaced. Others provide spacer washers that may be added or removed to vary the spring tension.

Following adjustment (on either vacuum or centrifugal advance unit), the distributor must be carefully checked against specifications on an accurate distributor test machine.

Such a machine may be used to check the distributor for dwell, point bounce, bent shaft, worn bushings, worn cam, and vacuum and centrifugal advance action.

COMPUTERIZED IGNITION SERVICE

Some vehicles are equipped with a computer that controls specific ignition system functions. Computerized systems often contain many of the same components found in electronic ignition systems. The fundamental difference between electronic ignition and computerized ignition is the way that each system advances the ignition timing. Electronic ignition systems use traditional centrifugal and vacuum advance systems. Computerized systems use sensors to monitor various operating conditions. The computer constantly adjusts the timing in response to these conditions, Fig. 23-37. Many computerized ignition systems have self-diagnostic capabilities. When a malfunction occurs, the computer stores a trouble code in its memory and ac-

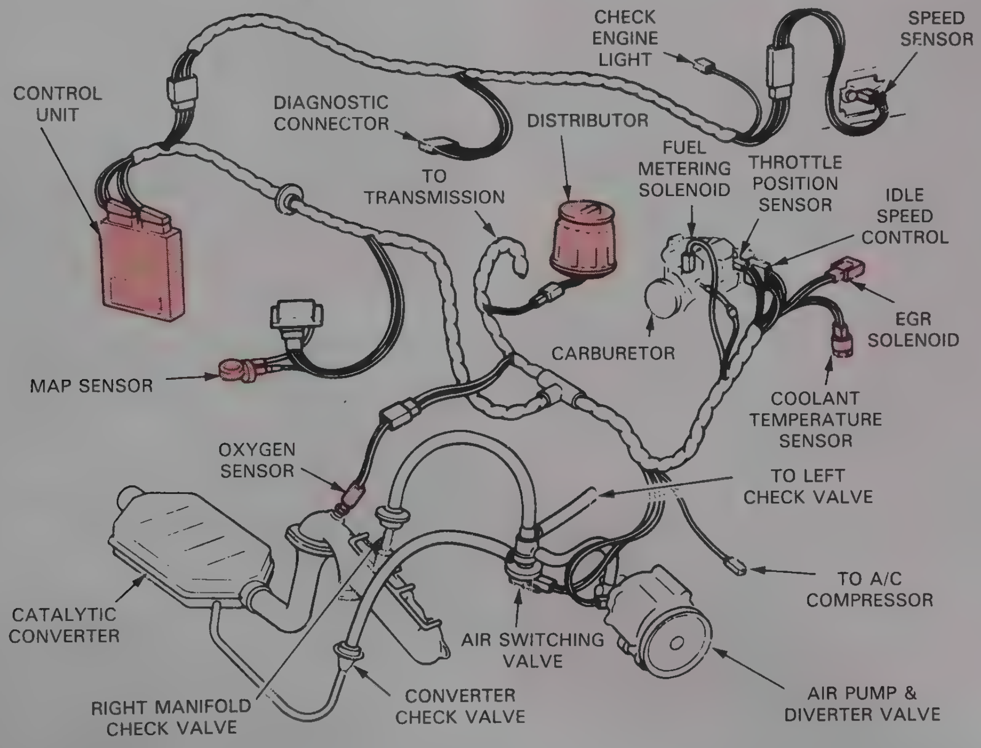

CHECK ENGINE LIGHT
SPEED SENSOR
CONTROL UNIT
DIAGNOSTIC CONNECTOR
DISTRIBUTOR
FUEL METERING SOLENOID
THROTTLE POSITION SENSOR
TO TRANSMISSION
IDLE SPEED CONTROL
EGR SOLENOID
CARBURETOR
MAP SENSOR
COOLANT TEMPERATURE SENSOR
OXYGEN SENSOR
TO LEFT CHECK VALVE
TO A/C COMPRESSOR
CATALYTIC CONVERTER
AIR SWITCHING VALVE
RIGHT MANIFOLD CHECK VALVE
CONVERTER CHECK VALVE
AIR PUMP & DIVERTER VALVE

Fig. 23-37. Schematic of a computer controlled ignition system. Note various sensors used to monitor engine operating conditions. (Sun Electric)

tivates a warning light on the vehicle's dash. The automotive technician can retrieve the trouble code by performing a specific test sequence or by using a special scan tool. The trouble code will indicate which circuit or component the technician can use as a starting point for diagnosis.

Computer-based ignition systems can be damaged by using the wrong test equipment or grounding the incorrect terminals. Proper connections are imperative. Follow all the manufacturer's service instructions carefully. Always turn the ignition switch off when connecting or disconnecting electronic components in computerized ignition systems. For more information about computerized control systems, sensors, and trouble codes, see Chapter 24.

OVERHAULING THE DISTRIBUTOR

Distributors must be overhauled when the bushing, shaft, gear, or cam wear becomes excessive, or when the advance mechanisms fail to function correctly. Note the areas of the typical distributor in Fig. 23-38 that could require overhaul.

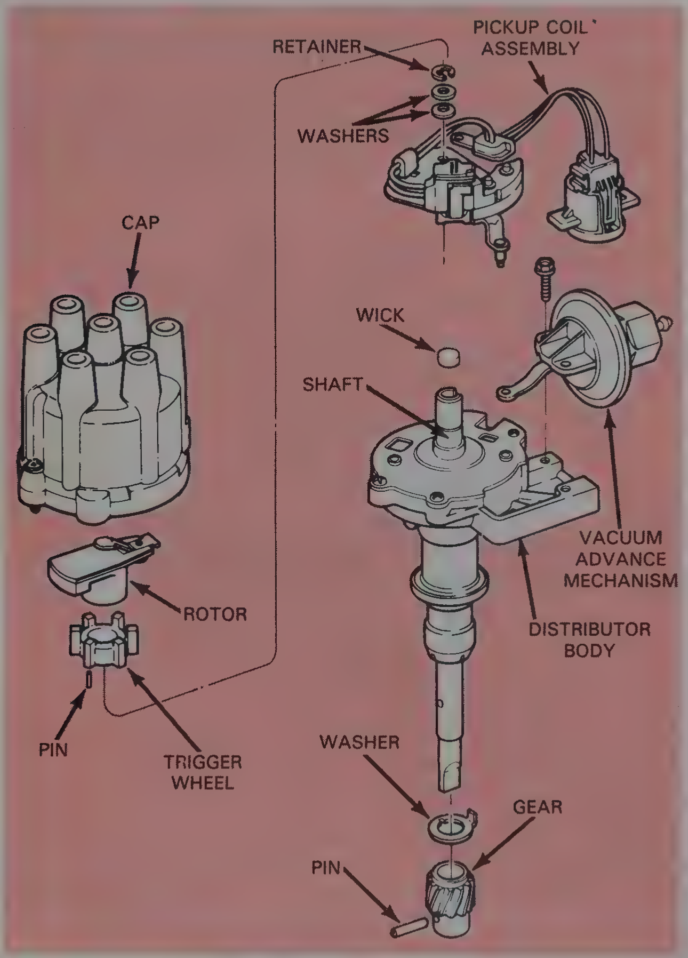


Fig. 23-38. Typical electronic ignition distributor. Note areas that could need replacement when worn, bent, or corroded. (American Motors)

Before removing the gear from the shaft, measure from the top of the gear to some reference point on the distributor housing (where used) and pull shaft. See Fig. 23-39. Where applicable, replace both upper and lower bushings if worn. Ream and burnish if required, Fig. 23-40.

Replace vacuum advance diaphragm unit if faulty. Clean and oil centrifugal advance. Replace rusty or stretched advance springs. Clean, examine, and oil movable breaker bushing or bearings as required. Replace the breaker cam if worn or rough. Replace shaft if worn, rough, or bent. Check housing for cracks or other damage. Check gear for chipping or wear.

Assemble distributor and check both shaft side and end play. MAKE SURE PIN IS THROUGH THE GEAR. IF PIN IS OF THE SOLID (not roll pin) TYPE, CHECK THAT IT IS SECURELY PEENED.

Lubricate as required. Install various components. Check out on a distributor tester.

INSTALLING DISTRIBUTOR

If the distributor was marked to indicate the position of the rotor and also scribed to show housing-to-

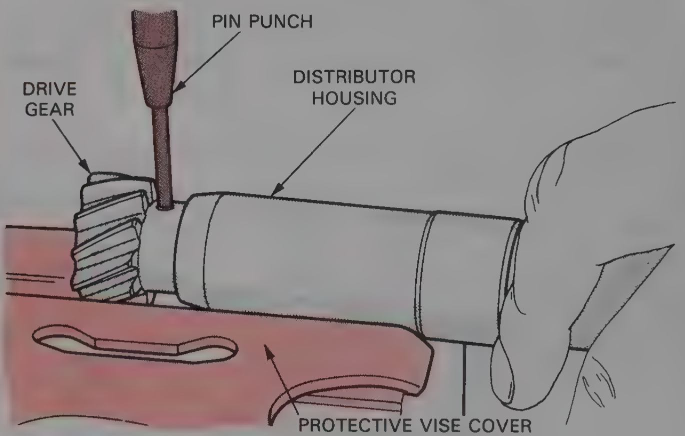


Fig. 23-39. Support gear and shaft when removing or installing retaining pin. (Plymouth)

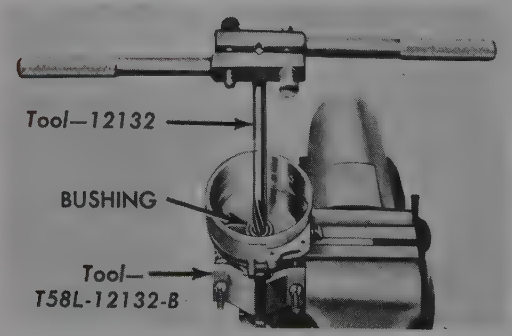


Fig. 23-40. Reaming a new distributor shaft upper bushing.

engine relationship, installation is simple. Align the rotor with the chalk or scribe mark. See Fig. 23-41.

Align the housing-to-engine block scribe lines. Push the distributor into place. As the distributor is moved down, you will notice that the rotor will turn a small amount as the distributor gear meshes. Pull the distributor up far enough to disengage the gear, move the rotor back far enough to compensate for the turning and press down again. When the housing flange is flush against the block, housing-engine and rotor-housing scribe lines should all be aligned. Lock distributor into place.

If the distributor will not bottom, DO NOT ATTEMPT TO FORCE IT DOWN BY USING THE HOLD-DOWN CLAMP TO DRAW IT IN. The distributor shaft is probably not aligned with the oil pump shaft slot or tang. Push the distributor downward by hand while cranking the engine. When the two shafts are aligned, the distributor will drop into place.

If the engine was cranked following distributor removal, crank the engine until the number one piston is starting up on the compression stroke. Turn engine over until the timing marks are aligned. Engine is now ready to fire number one cylinder. Align distributor housing-to-block scribe marks. Turn the rotor to face number one cap tower—points just starting to open. Press into place. Pull up and adjust for rotor movement. When correct, distributor will be fully bottomed. The points will just be opening, and the rotor will point at number one cap tower.

When the distributor is driven by the oil pump, it is necessary to align the pump gear as specified prior to inserting the distributor. If no specifications are available, bring engine into position to fire number one cylinder (see preceding paragraph). Distributor may then be meshed with the slot in the oil pump gear or shaft. Fig. 23-42 illustrates the recommended positioning for one type oil pump gear setup. When in this position, the distributor may be inserted.

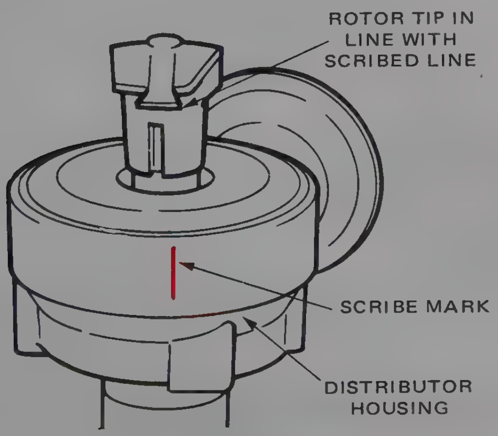


Fig. 23-41. Align rotor tip with scribe mark on distributor housing. (American Motors)

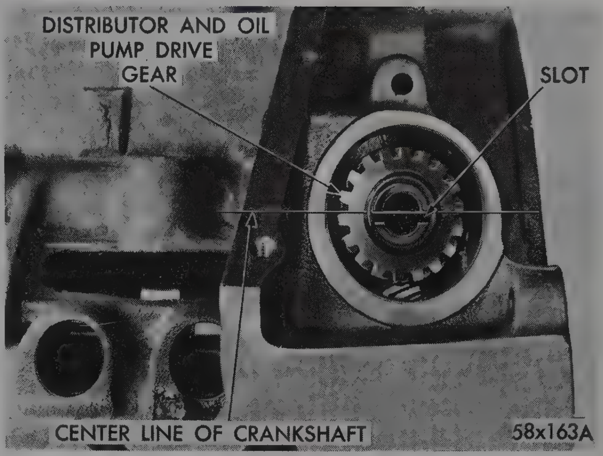

DISTRIBUTOR AND OIL PUMP DRIVE GEAR
SLOT
CENTER LINE OF CRANKSHAFT
58x163A

Fig. 23-42. On this engine, oil pump gear slot is aligned with centerline of crankshaft (number one piston on compression stroke, ignition timing marks aligned). If this gear has not been removed, it is only necessary to mesh distributor shaft tang with gear slot. Note how slot is offset.

TIMING DISTRIBUTOR

The distributor initial setting (timing mark aligned with pointer or scale, rotor facing number one plug wire tower and points just opening) will suffice for starting the engine. Flavor a slightly retarded setting (spark occurs LATER than specified) to prevent "kicking" (engine attempting to rotate backwards due to plug being fired too early) that could damage the starter mechanism.

If recommended by manufacturer, remove vacuum advance line and tape the vacuum fitting. Perform any other recommended steps.

Loosen the distributor clamp just enough to allow the distributor to be turned without undue force. Look at Fig. 23-43.

Attach a power (stroboscopic) timing light and tachometer as directed by the manufacturer, Fig. 23-44.

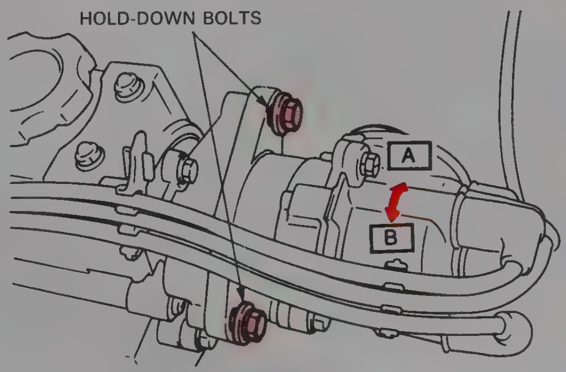


Fig. 23-43. Distributor assembly with two hold-down bolts. Turning the distributor toward "A" will advance the timing. The hold-down bolts must be torqued to specifications after timing is adjusted. (Geo)

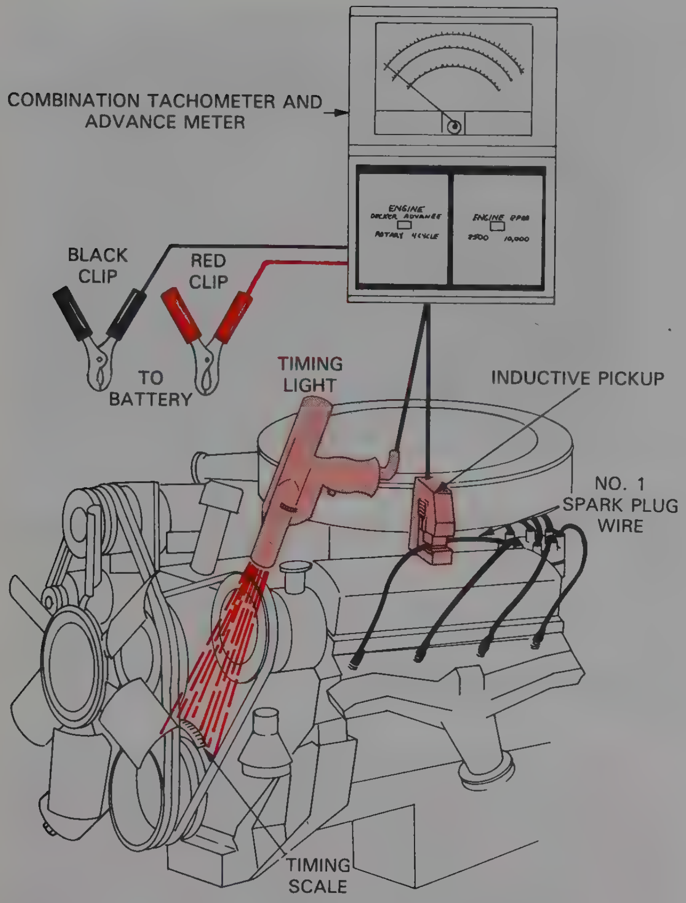

COMBINATION TACHOMETER AND ADVANCE METER
ENGINE
ENGINE RPM
2500
10,000
BLACK CLIP
RED CLIP
TO BATTERY
TIMING LIGHT
INDUCTIVE PICKUP
NO. 1 SPARK PLUG WIRE
TIMING SCALE

Fig. 23-44. Using a timing light to set ignition timing. Note use of inductive pickup. Battery not shown. (Snap-On)

If the engine has provisions for a magnetic probe, Fig. 23-45, the "monolithic" (electronic timing) may be used. Use either a jumper wire from plug to plug wire or use an inductive type pickup, as pictured in Fig. 23-44. Under no circumstances should the plug wires be pierced with a probe.

Clean off timing scale and index mark. Paint or chalk mark to make it more legible. See Fig. 23-45.

Some engines have a pointer on the block with the scale stamped on the vibration damper. The front wheel drive, transaxle setup, pictured in Fig. 23-46, uses a scale stamped on the flywheel. It is visible through an access hole in the bell housing. Note pointer, Fig. 23-46.

Check the underhood area to make certain all wires and tools are free of the fan and exhaust system. Start engine. DO NOT STAND IN LINE WITH FAN. KEEP WIRES AND FINGERS AWAY FROM THE MOVING FAN AND BELTS!

Idle at a recommended slow rpm to avoid bringing centrifugal advance into play. Direct the power timing light beam on the timing marks.

Turn the distributor as required to bring the painted mark in line with the scale or pointer. When the mark is EXACTLY in line, tighten distributor clamp. Recheck to make sure the mark is still aligned.

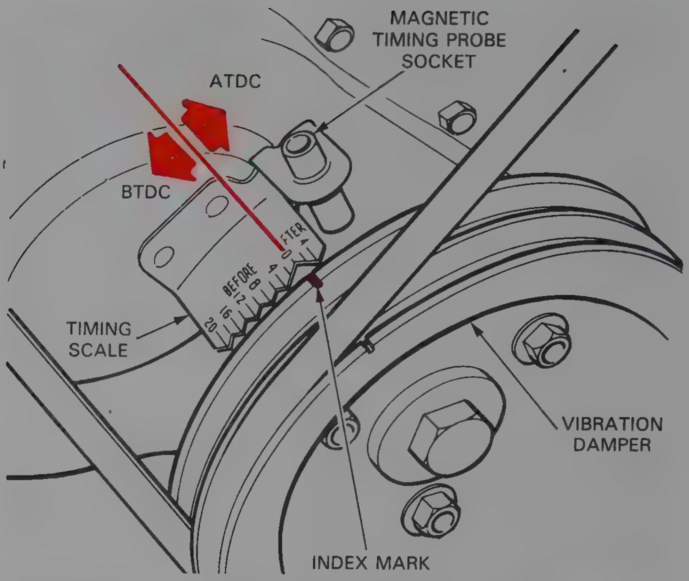

MAGNETIC TIMING PROBE SOCKET
ATDC
BTDC
AFTER
BEFORE
0
4
8
12
16
20
TIMING SCALE
VIBRATION DAMPER
INDEX MARK

Fig. 23-45. Clean timing scale and chalk or paint index mark for easy visibility. This setup has a magnetic timing probe socket to allow use of electronic timing equipment. (American Motors)

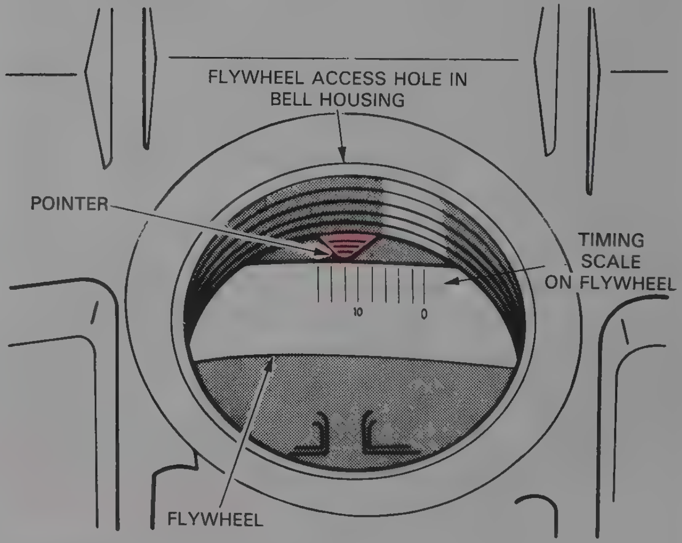

FLYWHEEL ACCESS HOLE IN BELL HOUSING
POINTER
TIMING SCALE ON FLYWHEEL
10
0
FLYWHEEL

Fig. 23-46. Timing marks as used on one front wheel drive car. Marks are visible through access hole in bell housing. (Plymouth)

ON BREAKER POINT IGNITION SYSTEMS, POINT GAP OR DWELL MUST BE SET BEFORE TIMING. CHANGING THE GAP WILL ALTER THE TIMING.

Replace vacuum hose and other parts. The vacuum and centrifugal advance function can be checked at this time.

DO NOT "ROAD TIME" ENGINE

For years, it was fairly common practice to give the ignition timing a final adjustment by test driving the car. The timing was advanced until a distinct "ping" or "spark knock" could be detected during heavy acceleration—high gear at lower speeds—20 to 30 mph. The timing was then retarded until the ping disappeared.

With lower compression, long stroke engines, this was acceptable practice. With the modern engine—WATCH OUT!

A very slight carbon buildup in a high compression engine will increase the compression a measurable amount. If the engine was road timed as described, the increased compression could cause a severe ping or spark knock that could literally pound holes through the head of the pistons. TIME THE ENGINE AS SPECIFIED BY THE ENGINE MANUFACTURER. CAUTION THE OWNER TO USE GASOLINE THE MANUFACTURER RECOMMENDS.

SPARK PLUG SERVICE LIFE

Spark plug service life varies a great deal depending on such factors as engine design, type of ignition system (breaker point or electronic), type of service, driver habits, and type of fuel. Under extreme cases, some plugs may require replacement at 5000 miles (8 000 km). Others may last beyond the often recommended replacement interval of between 15,000 to 30,000 miles (24 000 to 48 000 km) for electronic systems.

In deciding whether to clean and reinstall or replace the plugs, the mechanic should weigh the cost of services for cleaning, filing, and gapping in light of the remaining useful life.

Unless the plug is in truly sound condition, it usually pays to install new plugs.

SPARK PLUG CLEANING INTERVALS

When plugs receive periodic cleaning and gapping, they will function better and will last longer. Generally, it would be sound practice to clean and inspect plugs every 10,000 to 15,000 miles (16 000 to 24 000 km).

SPARK PLUG REMOVAL

Pull plug boot and wire assemblies carefully. Direct a stream of compressed air around the base of each plug to blow out any foreign material.

Using a plug socket (rubber lined), remove the plugs being sure that the gaskets (where used) are also removed. Keep plugs in order so that any peculiar plug conditions can be related to the cylinder concerned.

EXAMINE SPARK PLUGS

A careful study of the spark plugs is helpful in determining engine condition, plug heat range selection, and trouble resulting from operational conditions, Fig. 23-47 illustrates typical spark plug conditions.

SPARK PLUG PROBLEMS

Study Fig. 23-48. Note that in A, the plug fires normally. In B, a dirty insulator caused flashover. In C, a cracked insulator allowed the current to travel to ground. In D, conductive deposits on insulator allowed the current to travel to ground. In E, excessive gap raised required voltage above that available. In F, conductive deposits between the electrodes allowed current to travel to ground. In G, an overheated insulator nose fired the fuel charge (preignition) before the voltage could build up high enough to force the current to jump the gap.

CLEANING SPARK PLUGS

After studying each plug for signs of unusual performance, place them in a container of clean solvent. Clean plugs with a bristle brush and blow them dry. Make certain all oil is removed with solvent and that the plug is blown dry. Dampness around the insulator will cause the blast cleaner abrasive material to pack instead of clean.

Use a spark plug cleaning machine. Apply a stream of abrasive to clean away all deposits. See Fig. 23-49.

While applying the abrasive blast, rock the plug as shown in Fig. 23-50. This will assist in thorough cleaning.

DO NOT OVER-CLEAN

Apply the abrasive blast only long enough to clean the insulator and shell. If cleaning is continued beyond this point, the side electrode and insulator may be badly worn.

BLOW CLEAN

Blow each plug free of ALL abrasive. If a plug, contaminated with abrasive, is placed in the engine, the abrasive will work out and cause serious wear and scoring.

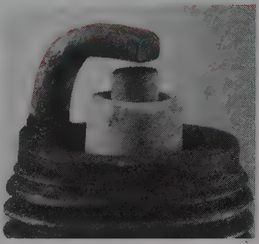
If the abrasive tends to pack in the plug instead of cleaning it, change the abrasive and bleed the air lines to remove moisture. An exception to this is when the cleaner uses water as a part of the cleaning process.

BRUSH THREADS

Use a hand wire brush to remove all carbon from the plug threads. Check the threads in the head. If they are carboned, rusty, or stripped, run a special spark plug tap through the holes.

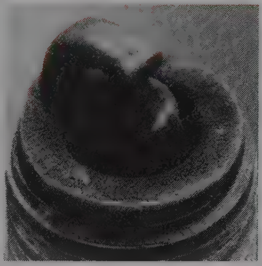
TYPICAL SPARK PLUG CONDITIONS

NORMAL PLUG APPEARANCE



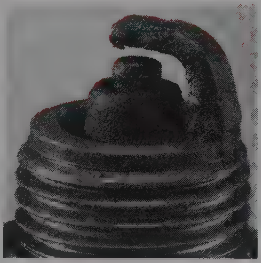
A spark plug operating in a sound engine and at the correct temperature will have some deposits. The color of these deposits should range from tan to gray. The electrode gap will show growth of about .001 in. (0.025 mm) per 1000 miles (1600 km), but there should be no evidence of burning.

FUEL FOULING



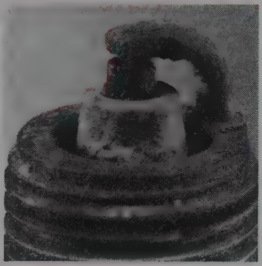
Fuel fouling (dry, fluffy, black carbon deposits) can be caused by plugs that are too cold for the engine, a high fuel level in the carburetor, a stuck heat riser, a clogged air cleaner, or excessive choking. If only one or two plugs show evidence of fuel fouling, inspect the plug wires for those cylinders. Sticking valves can also cause fuel fouling.

OIL FOULING



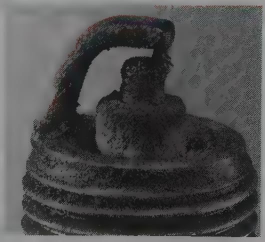
Oil fouling (wet, black deposits) is caused by an excessive amount of oil reaching the cylinders. Check for worn rings, valve guides, or valve seals. A ruptured vacuum pump diaphragm can also cause oil fouling. Switching to a hotter spark plug may temporarily relieve the symptoms, but will not correct the problem.

SPLASHED FOULING



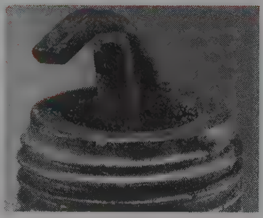
Splashed fouling (plugs coated with splashes of deposits) can occur when new plugs are installed in an engine with heavy piston and combustion chamber deposits. The new plugs restore regular firing impulses and raise the operating temperature. As this occurs, accumulated engine deposits flake off and stick to the hot plug insulator.

GAP BRIDGING



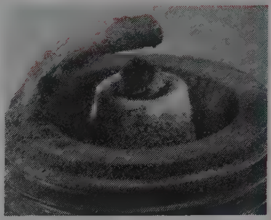
Gap bridging (carbon-lead deposit connecting the center and ground electrodes) is not often encountered in automotive engines. Prolonged low speed operation followed by a sudden burst of high speed operation can form gap bridging. It can also be caused by excessive fuel additives.

MECHANICAL DAMAGE



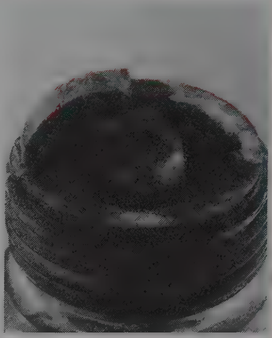
Mechanical damage can be caused by a foreign object in the combustion chamber. When a plug shows evidence of mechanical damage, all cylinders should be inspected. Valve overlap may allow small objects to travel from one cylinder to another.

OVERHEATING



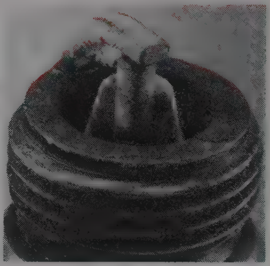
Overheating (dull, white insulator and eroded electrodes) can occur when the spark plugs are too hot for the engine. Cooling system problems, advanced ignition timing, detonation, sticking valves, and excessive high speed driving can also cause spark plug overheating.

PREIGNITION



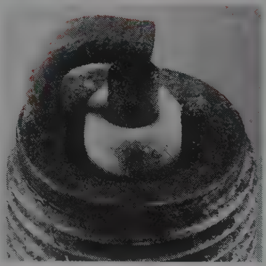
Preignition (fuel charge ignited by an overheated plug, piece of glowing carbon, or hot valve edge before the spark plug fires) will cause extensive plug damage. When plugs show evidence of preignition, check the heat range of the plugs, the condition of the plug wires, and the condition of the cooling system. The engine should be checked for physical damage because it has been subjected to excessive combustion chamber pressure.

DETONATION



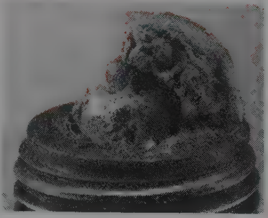
Detonation can cause the insulator nose on a spark plug to crack and chip away. The explosion that occurs during heavy detonation creates extreme pressure in the cylinder. Detonation can be caused by an excessively lean fuel mixture, low octane fuel, advanced ignition timing, or extremely high engine temperatures.

HIGH SPEED GLAZING



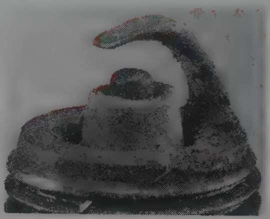
High speed glazing (hard, shiny, yellowish-tan, electrically conductive deposits) can be caused by a sudden increase in plug temperature during hard acceleration or loading. This condition often causes misfiring at speeds above 50 mph (81 km/h). If high speed glazing reoccurs, cooler plugs should be used.

ASH FOULING



Ash fouling (heavy white and yellowish deposits) is caused by the buildup of combustion deposits. The deposits may be caused by burning oil or fuel additives. Although ash fouling is not conductive, excessive deposits can cause spark plugs to misfire.

WORN OUT



Extended use will cause the spark plug's center electrode to erode. When the electrode is too worn to be filed flat, the plug must be replaced. Typical symptoms of worn spark plugs include a drop in fuel economy and poor engine performance.

Fig. 23-47. Spark plug appearance can help determine engine condition. (Champion Spark Plug)

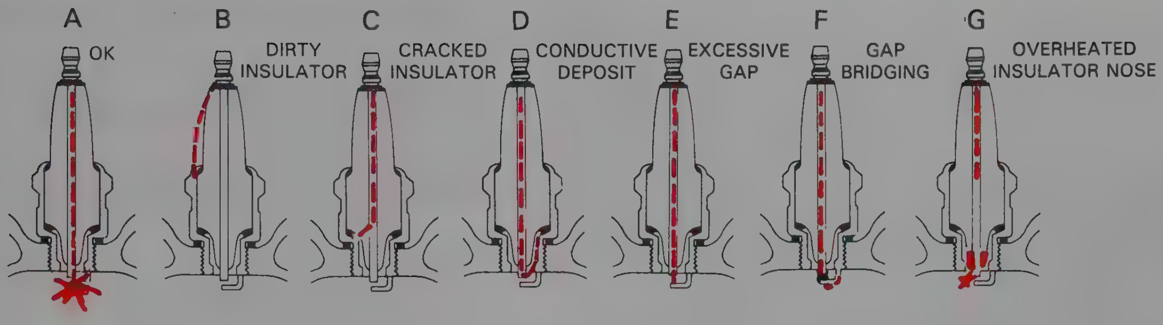

A
OK
B
DIRTY INSULATOR
C
CRACKED INSULATOR
D
CONDUCTIVE DEPOSIT
E
EXCESSIVE GAP
F
GAP BRIDGING
G
OVERHEATED INSULATOR NOSE

Fig. 23-48. Typical spark plug problems.

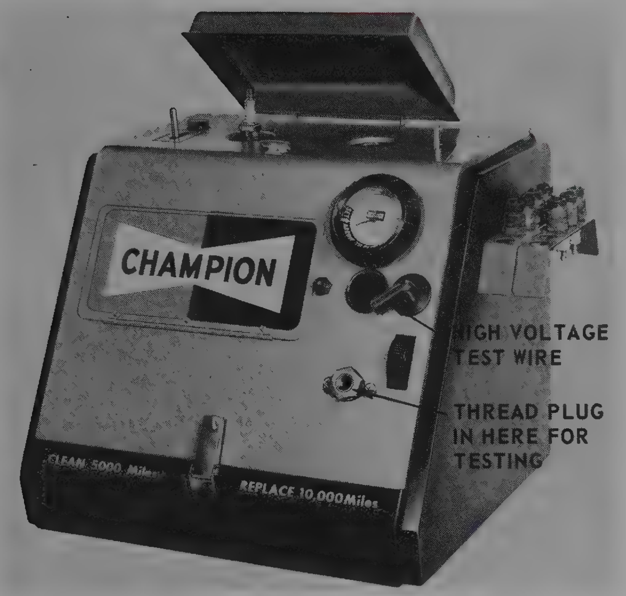

CHAMPION
HIGH VOLTAGE TEST WIRE
THREAD PLUG IN HERE FOR TESTING
CLEAN 5000 Miles
REPLACE 10,000 Miles

Fig. 23-49. Spark plug cleaning machine. This machine employs water as one ingredient, along with air pressure and a special Microbead cleaning compound.

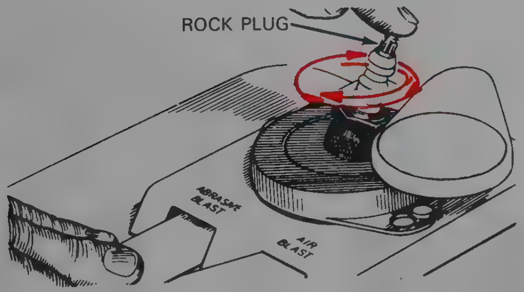

ROCK PLUG
ABRASIVE BLAST
AIR BLAST

Fig. 23-50. Rock spark plug while applying cleaning blast. This will expose all areas to abrasive.

FILE BOTH ELECTRODES

The plug cleaner cannot remove the oxidized metal and deposits from the gap area of the electrodes. If this area is not filed clean, the required voltage will remain high. The plug may misfire in service.

File the end of the inner electrode FLAT. File the inside of the side electrode FLAT. File the end SQUARE. This will remove all deposits and will produce SHARP EDGES that improve plug performance. Look at Fig. 23-51.

GAP THE PLUGS

After filing the electrodes, bend the SIDE electrode until the proper gap exists between the electrode surfaces. Gaps run between .030 to .060 in. (0.75 to 1.5 mm). Follow manufacturer's "specs." BEND ONLY THE SIDE ELECTRODE. Refer to Fig. 23-52. If any

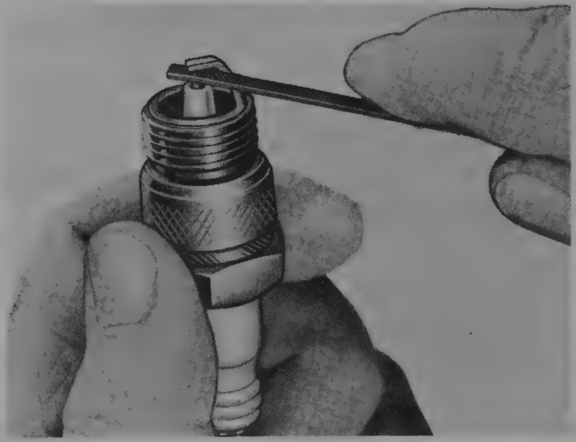


Fig. 23-51. File both electrodes to remove deposits and to produce square edges.

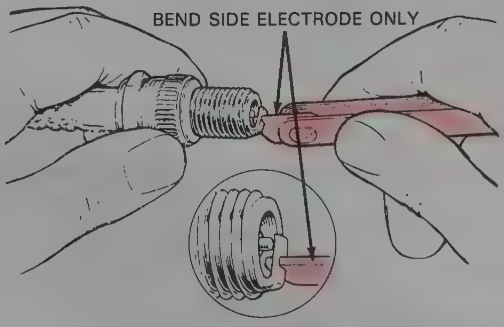

BEND SIDE ELECTRODE ONLY

Fig. 23-52. Bend SIDE ELECTRODE ONLY to adjust gap.

attempt is made to bend the center electrode, the insulator will be cracked.

Check for correct gap by using a WIRE feeler gauge. Note Fig. 23-53. Unless the plug is new, the flat feeler will not give accurate results because of electrode wear. Set plug gap as specified by manufacturer.

TEST PLUGS FOR FIRING EFFICIENCY

Test each plug on the cleaning machine. Discard those with a weak or intermittent spark. Follow machine manufacturer's test instructions. Note the high voltage wire and spot to insert the plug for testing, as in Fig. 23-49.

WASH AND BLOW DRY

Following testing, give the plugs a final rinse in CLEAN solvent and blow dry.

INSTALLING PLUGS

When using plugs that have been cleaned and gapped, use new gaskets (where needed), if available.

Wipe the plug gasket seat in the head. Insert the plug gasket in place where required (MAKE SURE ONLY ONE GASKET IS IN PLACE). Tighten until snug. Use a torque wrench to bring up to specified torque. Be careful to avoid placing side pressure on wrench. This could tip the socket and crack the plug insulator.

If no torque specifications are available, a good rule of thumb for plugs with new gaskets is to bring the plug up snug (finger tight). Then, give it about one-fourth to one-half turn more. For tapered seat plugs, turn up snug. Then, give it about one-sixteenth turn more.

Overtightening plugs can change the gap and cause other damage. Low torque will cause the plug to overheat and possibly cause preignition. Leakage and loosening can also result.

Wipe insulators clean and attach plug wires. Be careful to maintain the correct firing order.

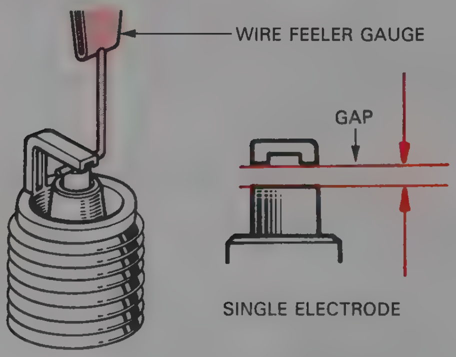


Fig. 23-53. Using a wire feeler gauge to adjust spark plug electrode gap. Set to manufacturer's specifications. (Toyota)

PLUG HEAT RANGE, SIZE, REACH, AND TYPE

When selecting new plugs, choose plugs having the specified heat range. A plug that is too cold will soon foul out with heavy deposits. A plug that is too hot will suffer from burning and preignition.

Notice that the plugs in Fig. 23-54, although of the same size and reach, have a different heat range. The heat range is controlled by the length of the insulator from the tip to the sealing ring. All other things being equal, the longer the insulator, the hotter the plug.

Size (18 mm, 14 mm, etc.) is determined by the diameter of the threaded section. Reach is determined by the length of the threaded section. Excessive reach can cause preignition, poor fuel charge ignition, difficult plug removal, and mechanical damage from striking a piston or valve.

Type indicates resistor, nonresistor, projected core nose, single ground electrode, or multiple ground electrode. See Figs. 23-54 and 23-55.

CHECKING THE IGNITION SYSTEM WITH AN OSCILLOSCOPE

The use of an oscilloscope in tune-up work, in conjunction with a tachometer, ohmmeter, voltmeter, and ammeter is becoming widespread. Properly used, it will provide fast and accurate information on all parts of the ignition system.

The oscilloscope produces a visual pattern or waveform on a screen (much like a TV set). See Fig. 23-56.

An ignition system in good order will create a NORMAL waveform or pattern on the screen. Fig. 23-57 shows the normal pattern for a breaker point ignition system.

PATTERN—(FIRING SECTION)

In Fig. 23-57, the points open at A. This creates a secondary voltage that fires the plug (firing line). The

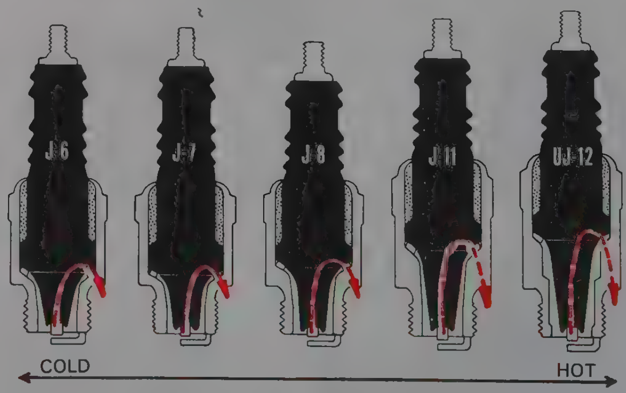


Fig. 23-54. Spark plug heat range is controlled by the length of the insulator exposed to the heat of combustion. Note heat escape path—red arrows.

amount of voltage required is indicated by the height of the firing line at B.

As soon as the plug fires, required voltage drops to C where it remains fairly constant (spark still jumping gap) to point D.

PATTERN—(INTERMEDIATE SECTION)

The spark goes out at D, Fig. 23-57. Starting at D, the coil and condenser dissipate their energy in a series of gradually reduced oscillations until the points close at E.

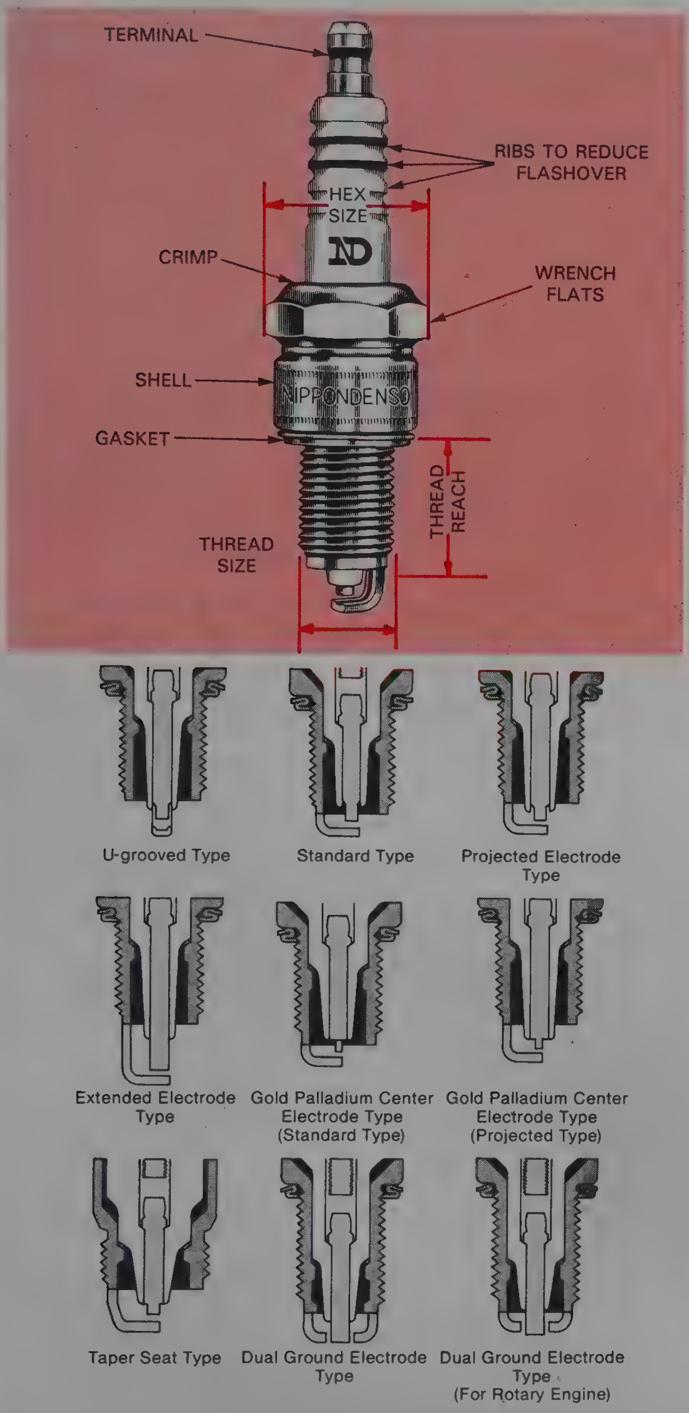

TERMINAL
RIBS TO REDUCE FLASHOVER
HEX SIZE
CRIMP
WRENCH FLATS
SHELL
NIPPONDENSO
GASKET
THREAD REACH
THREAD SIZE
U-grooved Type
Standard Type
Projected Electrode Type
Extended Electrode Type
Gold Palladium Center Electrode Type (Standard Type)
Gold Palladium Center Electrode Type (Projected Type)
Taper Seat Type
Dual Ground Electrode Type
Dual Ground Electrode Type (For Rotary Engine)

Fig. 23-55. Spark plug terminology. Note various types offered by this maker. (Nippondenso)

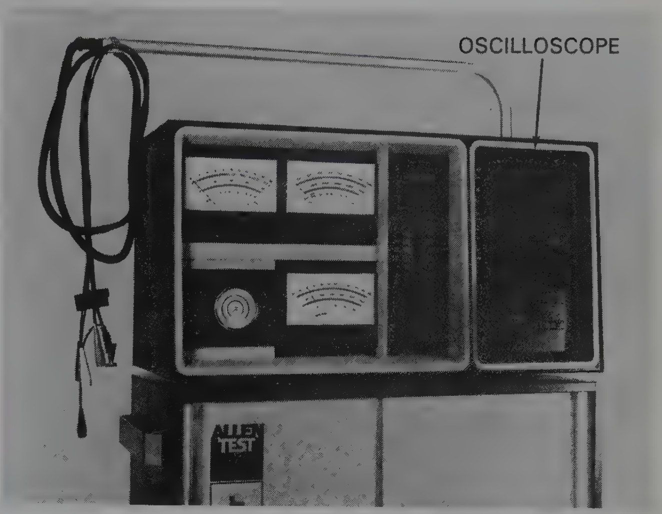

OSCILLOSCOPE
ALLEN TEST

Fig. 23-56. Engine test unit incorporating an oscilloscope. (Allen)

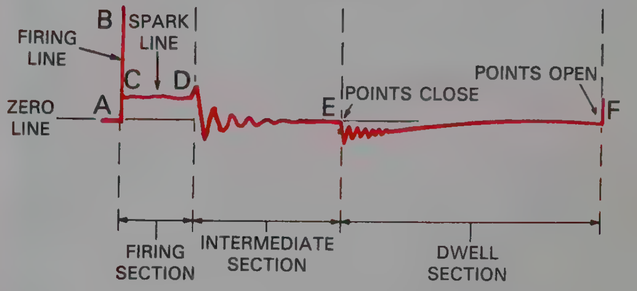

FIRING LINE
B
SPARK LINE
C
D
ZERO LINE
A
E
POINTS CLOSE
POINTS OPEN
F
FIRING SECTION
INTERMEDIATE SECTION
DWELL SECTION

Fig. 23-57. Typical oscilloscope NORMAL (system OK) pattern.

PATTERN—(DWELL SECTION)

The points close at E, Fig. 23-57. This closing action produces a series of small oscillations. The points remain closed (dwell period) from E to F.

PATTERN PRESENTATIONS

By means of adjustments, it is possible to view the pattern as produced by a single cylinder, A, Fig. 23-58; as cylinder patterns superimposed on each other, B, Fig. 23-58; or as all cylinders displayed on the screen at once but as separate patterns (parade), C, Fig. 23-58. A raster pattern displays the individual patterns formed by each cylinder. They are arranged in firing sequence, one above the other. This allows easy comparison for uniformity. Fig. 23-59 shows a secondary raster pattern.

The patterns formed by most electronic ignition systems are somewhat similar to those of the conven-

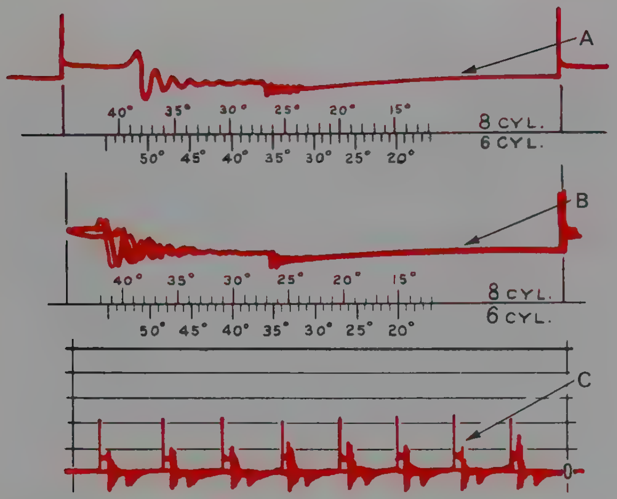


Fig. 23-58. Oscilloscope pattern presentations. A—Single cylinder. B—Superimposed. C—All cylinders or parade.

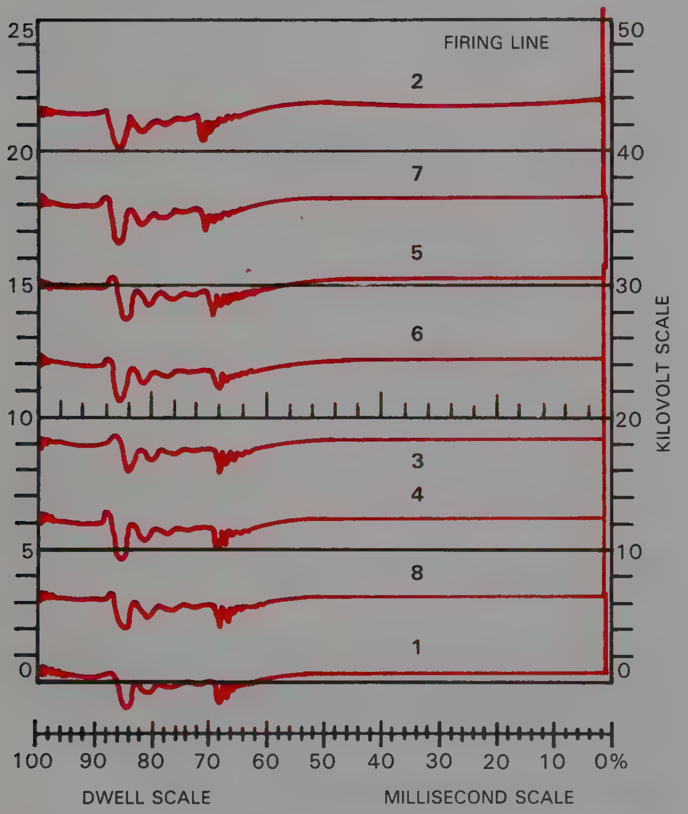


Fig. 23-59. Oscilloscope raster pattern. Each cylinder is displayed, one above the other, in order of firing. (Sun Electric)

tional contact point systems. Some electronic systems, such as the Chrysler EIS (Electronic Ignition System), however, show a marked difference. Note in Fig. 23-60, PRIMARY pattern, that the EIS system has no intermediate section.

When using an oscilloscope, be certain to follow the manufacturer's directions and pattern evaluation specifications for the EXACT system at hand.

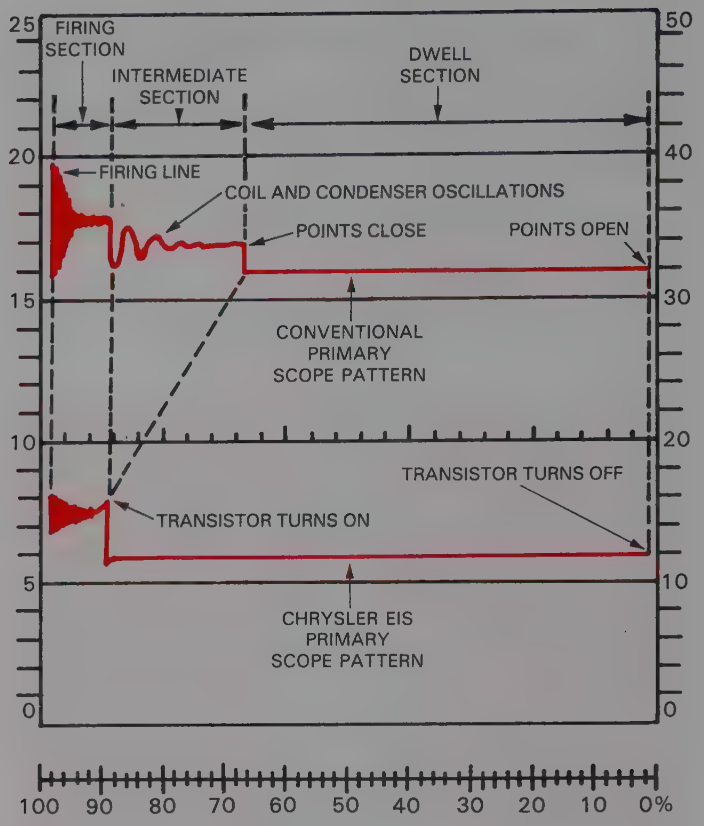

25
20
15
10
5
0
50
40
30
20
10
0
FIRING SECTION
INTERMEDIATE SECTION
DWELL SECTION
FIRING LINE
COIL AND CONDENSER OSCILLATIONS
POINTS CLOSE
POINTS OPEN
CONVENTIONAL PRIMARY SCOPE PATTERN
TRANSISTOR TURNS OFF
TRANSISTOR TURNS ON
CHRYSLER EIS PRIMARY SCOPE PATTERN
100 90 80 70 60 50 40 30 20 10 0%

Fig. 23-60. Comparison between a conventional breaker point ignition system pattern and that formed by the Chrysler EIS (Electronic Ignition System). Note intermediate section comparison. (Sun Electric)

OSCILLOSCOPE PATTERNS AND THEIR MEANINGS

Pattern irregularities provide clues as to what unit or units in the system are faulty and to what extent.

Accurate analysis of the various pattern irregularities requires that the mechanic be familiar with the machine in use. The mechanic must also be experienced in interpreting the patterns themselves. To become thoroughly skilled in the use of an oscilloscope as a diagnostic tool, be sure to practice whenever possible. Once the tool is understood and pattern irregularity meaning is clear, the mechanic will find this a very fast and efficient aid.

Fig. 23-61 illustrates six different patterns. Note that each one has specific irregularities that have a certain significance:

A. Normal pattern, firing voltages uniform but too high. Could be worn electrodes, lean fuel mix, or other similar problems.
B. Pattern normal but inverted. Caused by wrong coil polarity.
C. Normal pattern but firing voltages are uneven. Caused by defective plug wires, worn distributor cap, or similar type problems.
D. High resistance affecting all cylinders. Caused by high resistance in coil tower, coil wire, or rotor.
E. Irregular point opening pattern caused by burned or dirty points or high condenser series resistance.

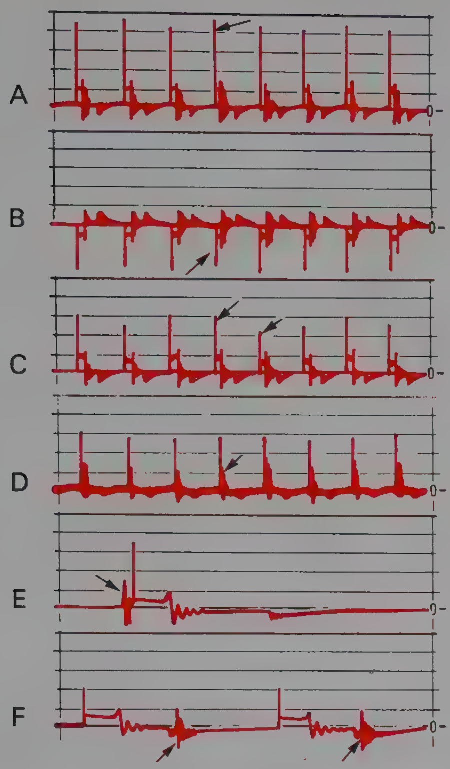


Fig. 23-61. Several pattern irregularities and their meanings. A—Firing voltage too high in all cylinders. B—Inverted pattern—wrong coil polarity. C—Firing voltages uneven. D—High resistance in all cylinders. E—Faulty point opening. F—Faulty point closing.

F. Irregular point closing pattern. Point bounce caused by weak breaker arm spring.

These six patterns represent only a few of the possible pattern irregularities. The manual supplied by the manufacturer of the equipment in your shop should be studied carefully.

ELECTRONIC IGNITION SPARK WAVEFORM PATTERNS

The electronic ignition system provides a rapid and intense current buildup in the coil. It also produces less voltage fluctuation (oscillation) following plug firing. See A and B in Fig. 23-62. At higher engine speeds, the conventional system available voltage drops considerably. The electronic system available voltage remains high. See C and D in Fig. 23-62.

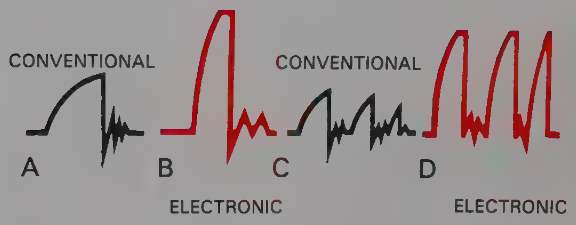


Fig. 23-62. Spark waveform patterns as produced by conventional versus electronic ignition system. (Ford)

BATTERY SERVICE

The battery plays a key roll in the overall functioning of the electrical system. To ensure reliability and to extend useful service life, the battery should receive periodic inspection and maintenance.

A visual inspection will help to determine which maintenance services are needed. Typical needs could include: cleaning of cable terminals, battery posts, and battery top; adding distilled water to cells (not needed with maintenance-free battery); tightening battery hold-down; battery charging, or replacement. A 12-volt side terminal battery is shown in Fig. 23-63.

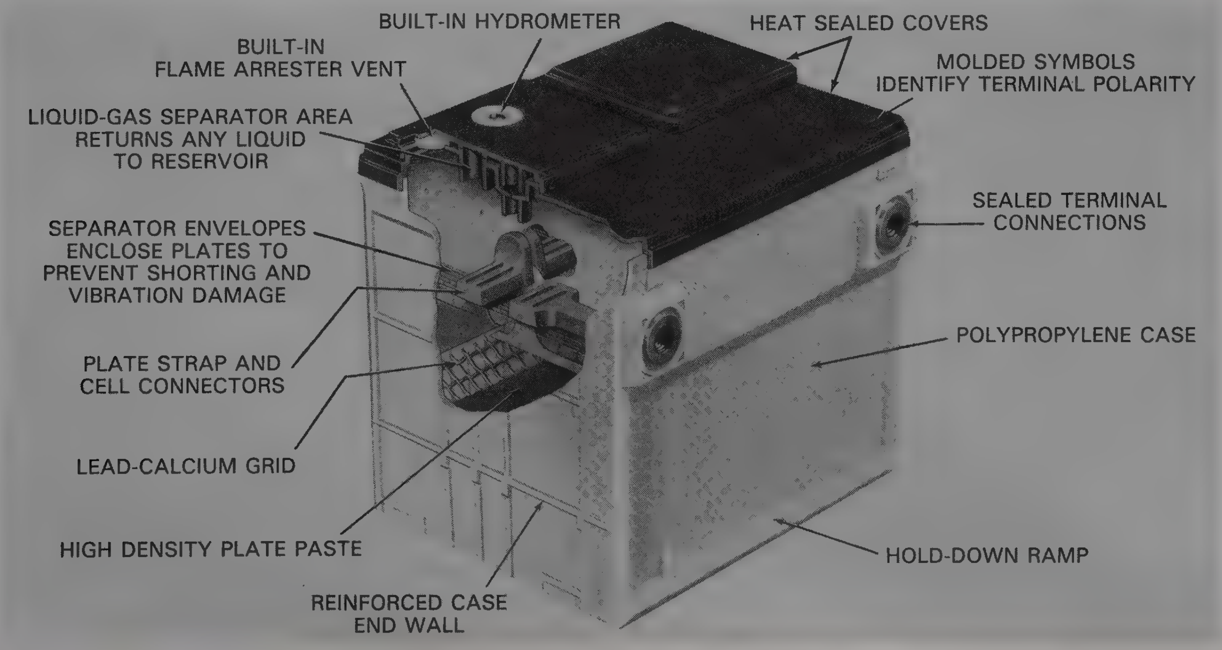

BUILT-IN HYDROMETER
BUILT-IN FLAME ARRESTER VENT
HEAT SEALED COVERS
MOLDED SYMBOLS IDENTIFY TERMINAL POLARITY
LIQUID-GAS SEPARATOR AREA RETURNS ANY LIQUID TO RESERVOIR
SEPARATOR ENVELOPES ENCLOSE PLATES TO PREVENT SHORTING AND VIBRATION DAMAGE
SEALED TERMINAL CONNECTIONS
PLATE STRAP AND CELL CONNECTORS
POLYPROPYLENE CASE
LEAD-CALCIUM GRID
HIGH DENSITY PLATE PASTE
HOLD-DOWN RAMP
REINFORCED CASE END WALL

Fig. 23-63. A typical 12-volt side terminal battery. Note sealed construction and use of built-in hydrometer. (General Motors)

BATTERIES CAN BE DANGEROUS

Battery electrolyte contains about 38 percent sulphuric acid and can cause serious skin and eye burns. If the electrolyte comes in contact with the skin, flush the area with large quantities of cold water. If in the eyes, flush with cold water and then consult a physician. Battery acid on the car or on clothing should be flushed with cold water. Follow with a mixture of baking soda and water to neutralize the acid.

The following safety rules should be observed at all times:

1. When handling battery electrolyte, wear goggles and rubber gloves.
2. If mixing sulphuric acid and water to make an electrolyte mixture, POUR ACID INTO WATER. DO NOT POUR WATER INTO ACID. Add acid slowly and stir constantly with a clean stick.
3. Never strike a spark, light a match, or bring other open flames near a battery. The charging process creates a mixture of hydrogen and oxygen gases which can ignite and burn with EXPLOSIVE FORCE. This could rupture the battery case and throw acid over a wide area.
4. Use a properly fitted lift strap to move batteries.
5. When a battery is removed from the car, place it where it will not be knocked over, dropped, or exposed to sparks or flame.
6. Store battery acid or dry-charge battery electrolyte where the containers will be safe from breakage.

IMPORTANT NOTE: This chapter describes procedures for handling many typical jobs. When testing either DC generator or alternator systems, instructions provided by the manufacturer of the test equipment should be carefully followed. Be sure to use specifications, voltage drop, current output, and voltage output specified for the exact make and model being tested.

CORROSION MUST BE REMOVED

Minute leaks and gassing (formation of hydrogen and oxygen gas) eventually attacks the terminals. This causes corrosion. Unless removed, the terminals will be eaten away. High resistance is also imparted in the terminal-to-post connection.

Use a wire brush to clean away the bulk of the corrosion. Remove the battery cable terminals. Plug the cap vent holes (if used) with toothpicks or masking tape. Brush a solution of baking soda and water over the terminals, posts, and battery top. Do not allow the baking soda mixture to enter the battery cells, Fig. 23-64.

Let the solution stand until the foaming action stops. Apply fresh solution to areas needing it. Rinse thoroughly with clean water.

Wipe the posts and terminals dry. Brighten posts and inside of terminals with sandpaper or a steel brush. Coat with nonmetallic grease. Install terminals and tighten securely. Install a protective terminal boot. Remove plugs from cap vents.

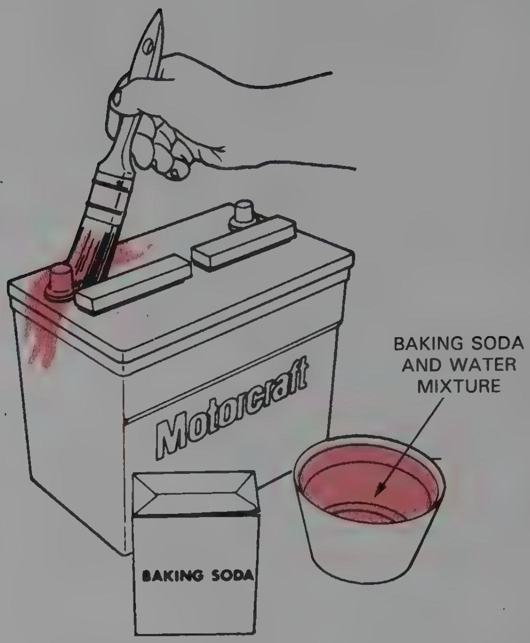

BAKING SODA AND WATER MIXTURE
Motorcraft
BAKING SODA

Fig. 23-64. A solution of baking soda and water can be used to clean corrosion from a battery. Do not allow solution to enter battery cells. (Ford)

A dirty battery top will attract electrolyte and become conductive. This deposit will allow a small but steady flow of current from one post to the other. Such a condition will cause slow discharge of the battery.

BATTERY HOLD-DOWN SHOULD BE SNUG

The battery hold-down device should be tight enough to hold the battery securely, but not tight enough to place excessive pressure on the case. Undue hold-down pressure can cause case failure.

Replace badly eroded hold-downs. Coat bolts and nuts with grease to protect against corrosion. Several efficient spray products are also handy to prevent corrosion.

CHECK ELECTROLYTE LEVEL

On batteries with fill caps, check the electrolyte level in each cell. Most batteries have a correct level indicator (slot, notch, lip). Add water to bring electrolyte up to the mark. If no mark is used, raise level to 3/8 in. (9.53 mm) above the top of the separators. TO PREVENT ELECTROLYTE LEAKAGE CAUSED BY EXPANSION PRESSURE, AVOID OVERFILLING.

When a battery uses an excessive amount of water, check system for overcharging. Prolonged overcharging will reduce battery life.

DISTILLED WATER

Although some tap water may be satisfactory for filling a battery, it is best to use DISTILLED WATER. Tap water in many areas has a high mineral content. It will prove injurious to batteries. Keep distilled battery water in a clearly marked container.

BATTERY EFFICIENCY

The efficiency of a given battery is determined by the state of charge, temperature, and mechanical condition of the plates, separators, and connectors.

Although it is difficult to determine the exact amount of useful life remaining in a battery, several tests (specific gravity, open circuit voltage, load tests) will give an indication of its ability to perform satisfactorily for a period of time.

If tests indicate a borderline condition, discard the battery. The little additional use that can be squeezed out by leaving the battery in service will be offset by the cost of charging, the possibility of a failure in the field, and the cost of a service call.

SPECIFIC GRAVITY TEST

The specific gravity of the electrolyte in a battery provides a handy method of determining the approximate state of charge. A fully charged battery will have a specific gravity from 1.260-1.280 (1.260-1.280 times heavier than an equivalent amount of pure water) at a temperature of 80°F (26.7°C).

As the battery becomes discharged, the sulphuric acid combines with the plate material. This leaves a lower percentage of acid in the electrolyte. In that the sulphuric acid is heavier than water, the reduction in acid content will reduce the electrolyte specific gravity. By measuring the specific gravity of a sample of the electrolyte with a hydrometer, the state of charge is indicated.

The chart in Fig. 23-65 shows the relationship between electrolyte specific gravity and state of charge.

State of Charge *	Specific Gravities as Used in Cold and Temperate Climates		Specific Gravity as Used in Tropical Climates
Fully Charged	**1.280**	**1.260**	**1.225**
75% Charged	**1.230**	**1.215**	**1.180**
50% Charged	**1.180**	**1.170**	**1.135**
25% Charged	**1.130**	**1.120**	**1.090**
Discharged	**1.080**	**1.070**	**1.045**

*State of charge as indicated by specific gravity when discharged at 20 hour rate.

The above are more or less typical specific gravity ranges. Gravity ranges will vary somewhat, depending on battery construction and ratio of electrolyte volume to active material.

Fig. 23-65. Relationship between specific gravity and battery state of charge. (AABM)

Specific gravity for a fully charged battery will vary for different types of batteries. The amount depends upon battery construction and climate where it is to be used.

A difference of more than 25 points (.025) between individual cell readings indicates that the battery is starting to fail due to internal shorts, normal deterioration from age and use, or loss of acid. If the highest cell specific gravity is below 1.190, charge and then retest. Perform the capacity (load) test for a more accurate picture of battery condition.

CHECK SPECIFIC GRAVITY WITH HYDROMETER

If the battery was just charged, crank the engine for several seconds to reduce the "surface charge" (electrolyte at top of battery temporarily having a higher than averge charge).

NEVER ADD WATER BEFORE CHECKING SPECIFIC GRAVITY. If the electrolyte level is so low that it is impossible to draw a sufficient amount into the hydrometer, add water and either charge the battery or check after a reasonable amount of car usage.

Hold the hydrometer in a vertical position and draw in enough electrolyte to suspend the float. Squirt this out and repeat several times to bring the float temperature to that of the electrolyte. The float should not touch either the bottom or top of the float barrel. Allow the gas bubbles to rise to the surface and any sediment to sink to the bottom before taking a reading. See Fig. 23-66.

The higher the specific gravity, the higher the float will ride out of the electrolyte. Hold the hydrometer at eye level. Note the scale reading at the exact point the float scale emerges from the electrolyte. This reading will have to be corrected by relating it to the standard 80°F (26.7°C) test temperature.

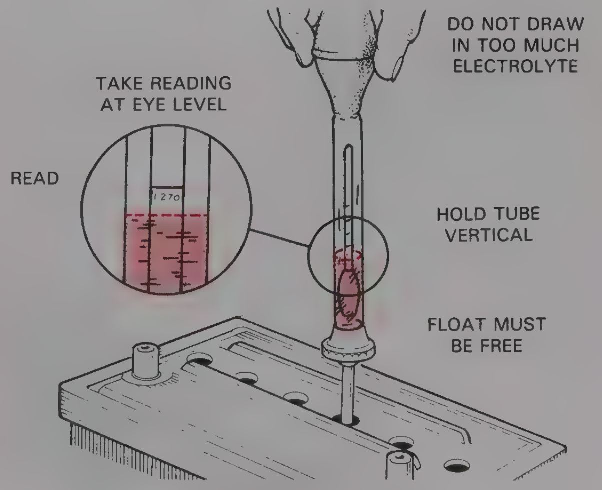

DO NOT DRAW IN TOO MUCH ELECTROLYTE
TAKE READING AT EYE LEVEL
READ
1270
HOLD TUBE VERTICAL
FLOAT MUST BE FREE

Fig. 23-66. Draw electrolyte into hydrometer until float is suspended free of both top and bottom of glass barrel. Read at eye leve. (British Leyland)

TEMPERATURE CORRECTED FLOAT READING

Note the temperature of the electrolyte by reading the thermometer built into the hydrometer. Add .004 to each 10°F (5.55°C) ABOVE 80°F (26.7°C) and subtract .004 for each 10°F (5.55°C) BELOW 80°F (26.7°C).

For example, assume that the float reading, Fig. 23-67, is 1.125 and that the solution temperature is 110°F (43.4°C). This would require ADDING .004 for each 10 °F (5.55 °C) above the 80 °F (26.7 °C) level or in this case adding .012 (3 x .004). This would give a corrected specific gravity reading of 1.137. See Fig. 23-67.

Cold weather reduces the efficiency of batteries. Even a new battery, fully charged, is affected. Fig. 23-68 illustrates how battery capacity (amount of electricity that can be drawn from a fully charged battery in a specified length of time) is reduced by cold.

Remember! A battery that cranks a car during moderate weather, may fail miserably during the first cold snap.

WHEN TO CHARGE BATTERY

When a hydrometer reading indicates that the battery is less than 75 percent charged (1.215-1.230), it should be recharged. Attempt to determine the reason for the low state of charge (regulator setting off, alternator bad, battery failing, excessive cranking).

BUILT-IN HYDROMETER

Many batteries are sealed and have a built-in hydrometer. Refer to Fig. 23-63.

Battery state of charge is indicated by the color of the built-in hydrometer or "eye" indicator. When the battery is charged, the indicator will show as a darkened area with a bright green (or other color on some batteries) dot in the center. A sound but discharged battery is indicated by a darkened indicator with no center dot. A battery that generally needs replacing will be indicated by a bright (clear) indicator with no dot. See Fig. 23-69.

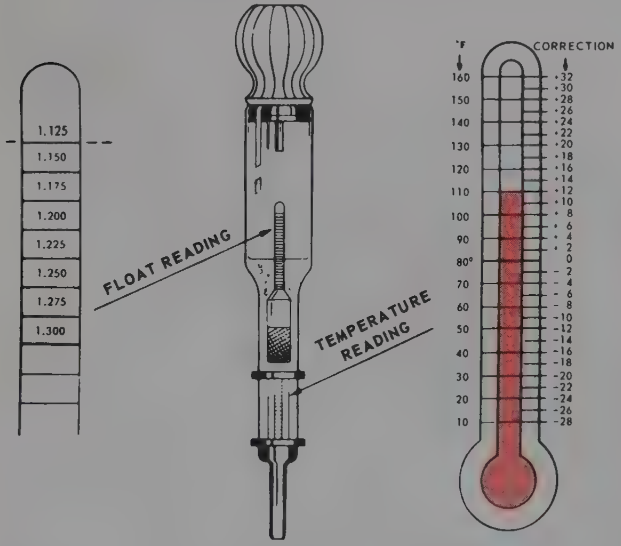

1.125
1.150
1.175
1.200
1.225
1.250
1.275
1.300
FLOAT READING
TEMPERATURE READING
°F
CORRECTION
160
150
140
130
120
110
100
90
80°
70
60
50
40
30
20
10
.32
.30
.28
.26
.24
.22
.20
.18
.16
.14
.12
.10
.8
.6
.4
.2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28

Fig. 23-67. Temperature correcting hydrometer float reading. (Ignition Mfg's. Inst.)

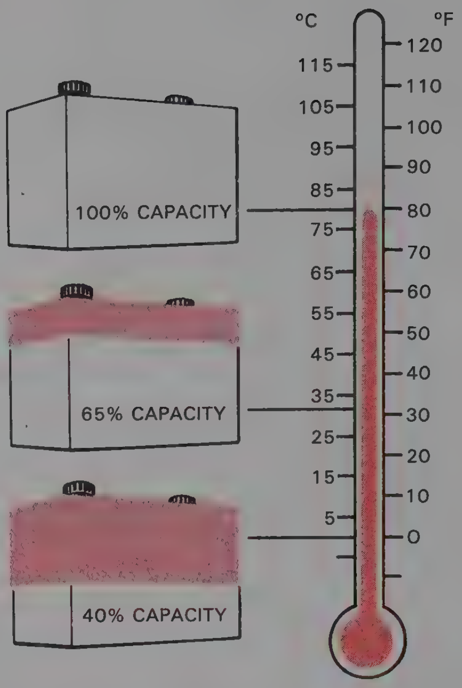

°C
°F
115
105
95
85
75
65
55
45
35
25
15
5
120
110
100
90
80
70
60
50
40
30
20
10
0
100% CAPACITY
65% CAPACITY
40% CAPACITY

Fig. 23-68. Battery capacity is greatly reduced by cold weather. Capacities at indicated temperatures are for sound, fully charged batteries. (Gulf Oil)

CHECKING OPEN-CIRCUIT VOLTAGE

The open-circuit voltage test (no load on the battery) is performed with a voltmeter. The battery cables must

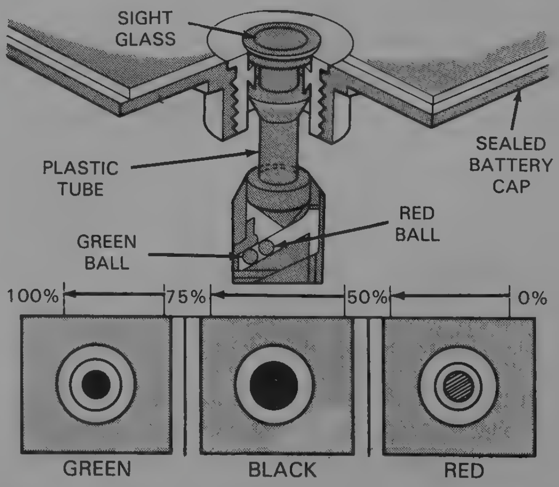

SIGHT GLASS
PLASTIC TUBE
SEALED BATTERY CAP
RED BALL
GREEN BALL
100%
75%
50%
0%
GREEN
BLACK
RED

Fig. 23-69. Battery state of charge indicator "eye" (built-in hydrometer) provides a fast check on battery condition. (Chrysler)

be disconnected for this test. Always remove the NEGATIVE cable first. If the battery was recently charged, boosted, or load tested, allow it to stabilize for 15 minutes before starting the test. Connect the meter leads to the battery terminals. Make sure the positive meter lead is connected to the positive battery terminal and the negative lead is connected to the negative terminal. The voltage reading across the terminals will indicate the "percentage of charge" in the battery, see Fig. 23-70. Open-circuit voltage should be approximately 12.6 volts. Note the relationship between open-circuit voltage and the percentage of charge.

BE CAREFUL – A CHARGING OR JUST CHARGED BATTERY WILL HAVE A GREAT DEAL OF HYDROGEN AND OXYGEN GAS IN THE CELLS. A SPARK FROM THE VOLTMETER PRODS COULD IGNITE IT.

CAPACITY (LOAD) TEST

Specific gravity and open-circuit voltage readings provide a general indication of battery condition. However, a more accurate appraisal may be made by making a capacity test.

DO NOT ATTEMPT THE CAPACITY TEST IF THE SPECIFIC GRAVITY IS BELOW 1.220. When the specific gravity is below 1.220, the battery should be SLOW charged until fully charged before testing.

Attach the capacity tester as directed by the manufacturer. The carbon pile load (a device used to place an adjustable electrical load in circuit) switch should be OFF to prevent sparking when attaching leads.

Connect ammeter and voltmeter positive leads to the battery positive post. Connect negative leads to the negative post. The voltmeter clips must connect to the battery post or cable terminals and not to the ammeter lead clips. See Fig. 23-71.

Adjust the carbon pile to place a load (in amperes) on the battery equivalent to THREE TIMES THE BATTERY AMPERE HOUR RATING. Keep this load applied for 15 seconds. At the end of this time, a voltmeter reading of 9.5 volts or more (4.8 or more for 6-volt batteries) indicates ample capacity. Be certain to correlate the voltage reading with battery temperature.

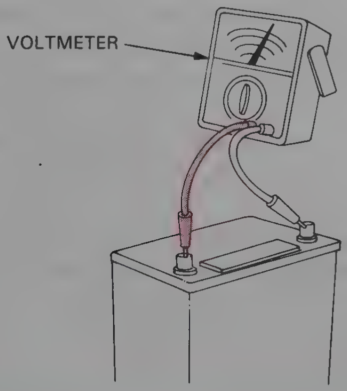
If the battery specific gravity was 1.220 or more before testing, no additional service is required. However, if the specific gravity was below 1.220 and the battery was charged prior to making the test, check the charging circuit. Determine the cause of the original discharged state.

A reading of less than 9.5 volts (4.8 volts for 6-volt batteries) indicates a possible poor condition. The battery should be given the three minute charge test.

THREE MINUTE CHARGE TEST

BATTERY TEMPERATURE MUST BE ABOVE 60°F (15.6°C) BEFORE MAKING THIS TEST. DO NOT GIVE THIS TEST TO BATTERIES UNLESS THEY HAVE FAILED THE CAPACITY TEST. DISCONNECT BATTERY CABLES IF BATTERY IS IN THE CAR.

Connect the battery charger positive lead to the battery positive post—negative lead to negative post. Set timer to three minutes (turn timer past three minute mark and then carefully back to mark). Adjust charging rate to 40 amp. (75 amp. for 6-volt battery). See Fig. 23-72.



BATTERY OPEN CIRCUIT VOLTAGE	
Open Circuit Volts	Percent Charge
11.7 volts or less	0%
12.0	25%
12.2	50%
12.4	75%
12.6 or more	100%

Fig. 23-70. Checking open-circuit voltage with a voltmeter. Follow test instrument operating instructions carefully. (Dodge)

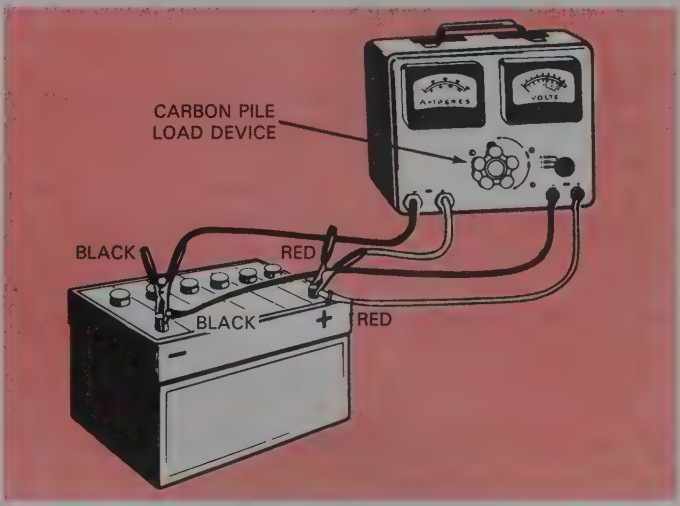


Fig. 23-71. Hookup for testing battery capacity. (Plymouth)

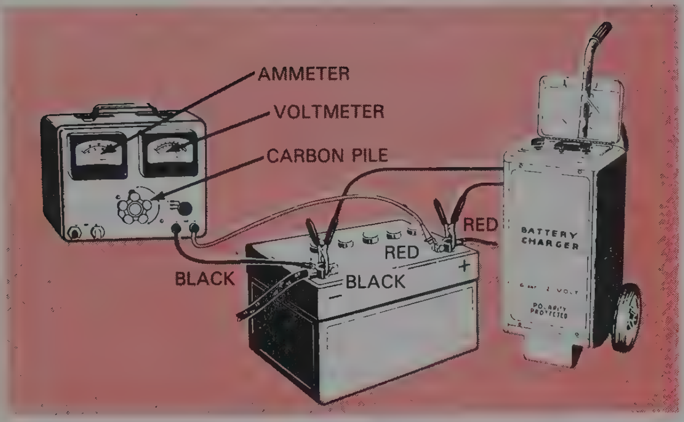


Fig. 23-72. Setup for conducting three minute charge test. (Sun Electric)

Apply the 40 amp. charge to the battery for three minutes. At the end of this time, charger still ON, check the voltmeter reading. If the voltmeter reads OVER 15.5 volts (7.75 for 6-volt), REPLACE THE BATTERY. If it reads under 15.5 volts, test individual cell voltages with charger still on. If cell voltages differ more than 0.1 volt, REPLACE THE BATTERY. If cell differences are under 0.1 volt, charge battery and place in service.

LIGHT LOAD BATTERY TEST

Another handy test for battery condition may be conducted with only a voltmeter (must read in at least .01 volt divisions).

Crank the engine with the starter for THREE SECONDS. Then turn the headlights on LOW BEAM. Leave on for ONE MINUTE and then test individual cell voltages with the lights still on.

If the cells read 1.95 volts or more and if the individual readings differ less than .05 volt, the battery may be considered sound. A reading of less than 1.95 volts on any cell, with a cell difference less than .05 volt, indicates a good battery. However, the battery needs to be charged.

A reading of 1.95 volts or more on any cell, but with a cell difference of more than .05 volt, indicates a defective battery.

A cell reading of under 1.95 volts on ALL CELLS indicates the need for charging and retesting. See Fig. 23-73.

BATTERY CHARGING

Batteries, in sound mechanical condition, may be brought up to full charge. A battery charger is used to pass a metered amount of DC (direct current) electricity through the battery in a direction OPPOSITE to that of normal movement. FAST charging or SLOW charging may be used.

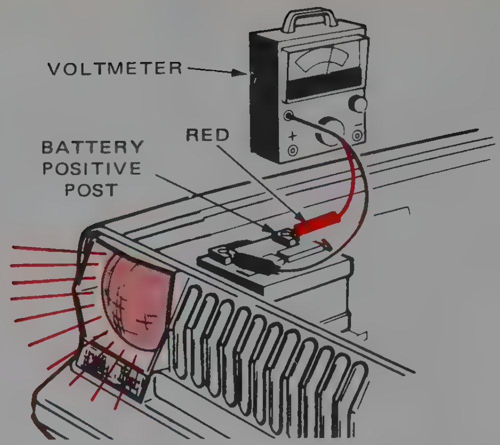


Fig. 23-73. Light load test for battery condition. (Jeep)

SLOW CHARGING

Slow charging passes a relatively small amount (5-7 amps.) of current through the battery for a fairly long period (14-16 hours or longer).

Slow charging is preferred to fast charging if time is available. However, a sound battery will not be damaged by proper fast charging. In that the battery cell condition is not always known, the slow charging minimizes the risk of possible damage through fast charging. Heavily sulphated (plate active materials changed to lead sulphate which resists essential chemical reactions) batteries heat quickly under fast charging. They respond better to slow charging.

To determine the approximate charge, you may consider 7 percent of the rated ampere-hour capacity of the battery as satisfactory. If in doubt as to the ampere-hour rating, charge at about 5 amps.

Clean the battery and fill to recommended level. Replace the cell caps where used. If the battery will remain in the car, disconnect the cables to prevent damage to radio or ignition transistors in the event the charger leads are hooked up wrong.

Attach the charger POSITIVE lead to the battery POSITIVE post. Connect the NEGATIVE lead to the NEGATIVE post.

If more than one battery is being charged, connect the batteries in series (positive post to negative post), Fig. 23-74.

Set the rate of charge to correspond to that for the smallest ampere-hour battery in the group. Switch to 6 or 12 volts as the case may be. The batteries will generally be fully charged within 12-16 hours although a sulphated battery may require longer. Leave each battery on the charger until the specific gravity indicates it is fully charged or until the specific gravity fails to raise during three additional readings taken at one hour intervals.

Watch battery temperature during charging. If it exceeds 125 °F (51.7 °C), lower the charge rate. Temperature in excess of 125 °F (51.7 °C) will cause serious battery damage. Be certain to remove the battery when charged. Overcharging is harmful.

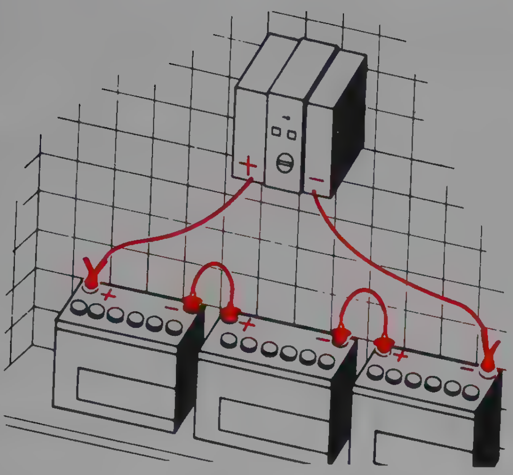


Fig. 23-74. Batteries connected in series for SLOW CHARGING. (Prestolite)

FAST CHARGING

Fast charging sends a relatively heavy initial current (50-60 amps. for 12-volt batteries) through the battery. This will impart a fairly good charge in a reasonably short time (one to two hours).

Prepare battery as directed under slow charging. DISCONNECT BATTERY CABLES. Hook fast charger positive lead to battery positive post—negative lead to negative post. Set current control as directed. Switch to either 6 or 12 volts as needed. Turn charger on. If electrolyte level is too high (expansion occurs during fast charging), place surplus in a clean glass and return after battery cools down (not applicable to maintenance-free types).

As the battery begins to take on a charge, the charger current will automatically lessen (if it is a constant potential type).

A fast charger will not bring a battery up to full charge. When the battery is about three-fourths charged, use a slow rate to bring it up to full charge.

Watch battery temperature. If it reaches 125°F (51.7°C), lower the charge rate at once.

If the specific gravity does not show a considerable increase within an hour, try the slow charge method.

If more than one battery is to be charged with the fast charger, hook the batteries in parallel. Do not attach both 6- and 12-volt batteries in the hookup. See Figs. 23-75 and 23-76.

TRICKLE CHARGING

Wet batteries (batteries containing electrolyte) that must be kept for any length of time are often placed on a trickle charger. The trickle charger passes a very low current, often less than one ampere, through the batteries.

Despite the small current, batteries can be damaged from overcharging. Many shops shut off the trickle charger during the night to help prevent overcharging.

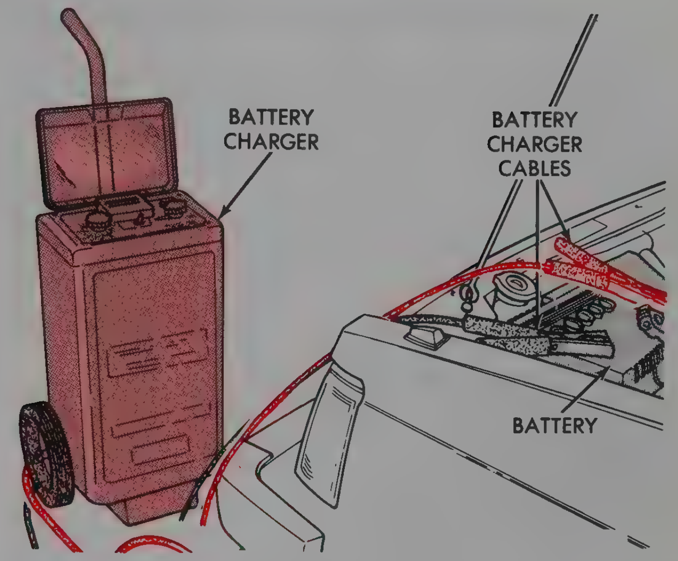


Fig. 23-75. Fast charging a battery. To prevent possible system damage, disconnect battery cable connectors BEFORE attaching charger cables. (Plymouth)

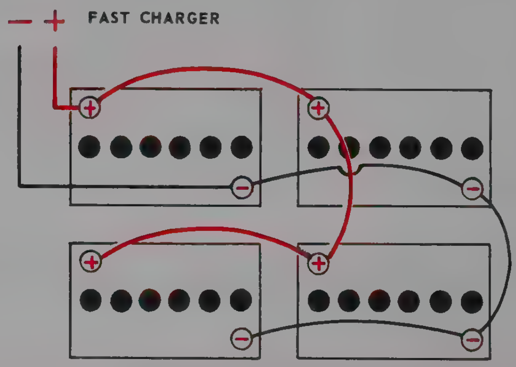


Fig. 23-76. Connect batteries in parallel for fast charging.

BATTERY STORAGE

If a wet battery is not to be trickle charged, it is advisable to store in a cool, dry area. A battery stored at 0°F (−17.8°C) will retain a charge for nearly a year, while the same battery at 125°F (51.7°C) will lose its charge within a month.

Dry-charged batteries (batteries with plates charged but which contain no electrolyte) must be stored in a cool, dry area with as even a temperature as possible. Although the dry-charged battery will retain its charge over a long period of time, it is wise to activate the battery by the end of the third year of storage.

ACTIVATING DRY-CHARGED BATTERY

Despite the fact that the use of dry-charged batteries is widespread, many shops fail to understand the importance of proper activation (preparing battery for service).

When activating a dry-charged battery, observe the following instructions. Take the time needed to do the job right. This will avoid unnecessary comebacks and complaints.

Remove cell caps. Remove cell cap vent plugs. Add SPECIFIED electrolyte to each cell until the separators are just covered (this allows room for expansion during charging). Use a glass or plastic funnel. NEVER USE A METAL FUNNEL. Replace caps.

Place the battery on the charger and apply a 35 amp. charge to 12-volt batteries—65 amp. for 6-volt. If excessive gassing occurs, lower the charge rate. CONTINUE CHARGING UNTIL THE SPECIFIC GRAVITY REACHES AT LEAST 1.240 AND THE ELECTROLYTE TEMPERATURE IS 80°F (26.5°C) OR ABOVE. IT IS IMPORTANT THAT BOTH SPECIFIC GRAVITY AND TEMPERATURE REACH THE LEVELS INDICATED.

Add ELECTROLYTE (not just water) to bring the level up to the mark. If using a disposable electrolyte container, wash out with water and discard.

Install the battery properly. (See Battery Removal and Installation.) See Fig. 23-77.

BATTERY SELECTION

When selecting a replacement battery, choose one equal or greater in ampere-hour capacity to the original.

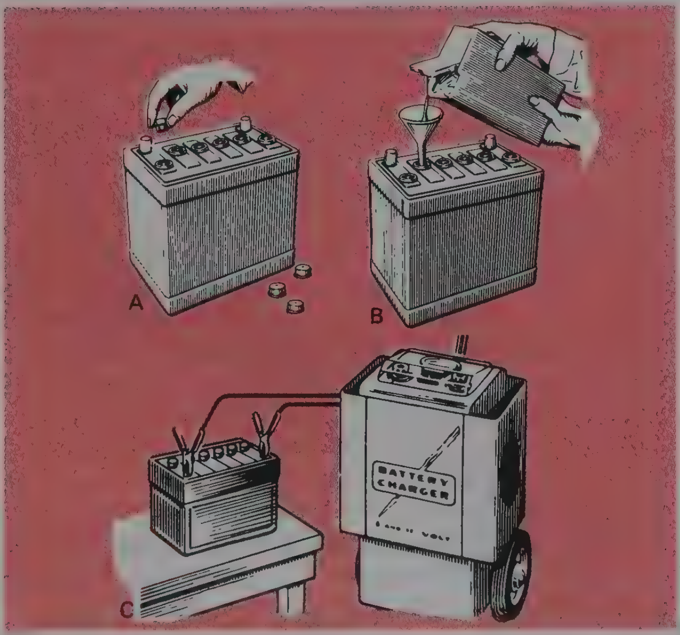


Fig. 23-77. Some steps in activating a dry-charged battery. A—Remove cell caps. Unplug vents. B—Add specified electrolyte. C—Fast charge until battery specific gravity reaches 1.240 and electrolyte temperature is at least 80 °F (26.7 °C). (Shell Oil)

When additional electrical devices have been added or if the vehicle is placed in a type of service that is hard on the battery, it is wise to select a battery of greater capacity.

Battery case physical size is classified as Group 1, Group 2, etc., while electrical size is measured in terms of voltage and ampere-hour capacity.

If a larger physical size battery is desired, be certain to check the holder for ample room. Also check vertical height in case the hood is relatively close to the battery when closed.

Various ampere-hour capacity batteries are available within a given group size.

Never place a 6-volt battery in a 12-volt system or vice versa.

BATTERY RATINGS

Battery performance is commonly rated in three ways: CRANKING PERFORMANCE (Indication of how high a discharge load in amperes the battery can provide in a period of 30 seconds under specified test condition); 20-HOUR RATING (Indicates how long battery will sustain specified rate of discharge before terminal voltage drops to 10.5 volts); RESERVE CAPACITY RATING (Indication of how long a battery will continue to provide normal electrical needs of vehicle following charging system failure).

Overall battery capacity, for any given battery, is largely dependent upon the number of plates, plate size, and amount of acid in the electrolyte.

BATTTERY ADDITIVES

It is recommended that NOTHING but pure tap or distilled water ever be aded to a battery. Do not add acid unless the battery has been overturned or the electrolyte has leaked out. The use of additives to supposedly improve capacity or prolong battery life, unless specifically approved by the battery manufacturer, can void the guarantee.

BATTERY REMOVAL AND INSTALLATION

Cover the fender with a protective pad. Before removing the battery cable terminals, note which battery post is grounded. Common practice on American-made cars is to ground the negative post.

Loosen terminal fasteners. If the terminals are difficult to remove, use a battery terminal puller. Never pound or twist the post or side terminals in an attempt to loosen.

Always remove the ground terminal first and, when installing the battery, replace it last.

Remove the hold-down plate. Put on safety glasses. Using a battery lift strap, remove the battery from the car. Make sure the lift strap is securely attached so that it will not slip. See Fig. 23-78.

Before installing a battery, check the battery holder for signs of corrosion. Remove with baking soda and water, if available. Make certain holder is structurally sound enough to support the battery.

Place battery in holder so that terminals are properly positioned with respect to the cables. Replace battery hold-down if badly corroded. If corroded but still usable, clean with baking soda and water. Dry and paint with acid-proof paint. Install hold-down. Do not overtighten. Clean battery terminals until bright. Coat with nonmetallic grease.

BATTERY POLARITY MUST BE CORRECT

Before attaching the terminals, make certain that the correct polarity will be maintained. If the polarity is reversed by accidentally reversing the terminals, the diodes in the alternator, transistors in the radio, ignition system, or fuel injection control unit will be ruined when the engine is started or the radio is turned on. Keep radio off when working on the battery.

The positive post can be identified by being wider in diameter than the negative post. The positive post may be painted RED and may have a +, or the letters P or POS stamped on the top.

The negative post may be painted BLACK on the top, and may be marked with a −, N, or NEG.

If in doubt as to whether to ground the POS or NEG post, refer to the manufacturer's manual.

Attach terminals so they will not prevent cell cap removal. Tighten securely. Make sure cables have enough slack to prevent imposing a strain on the connections and that they are in good condition.

Check ground cable where it attaches to frame. The connection must be CLEAN and TIGHT.

Tighten starter and solenoid connections.

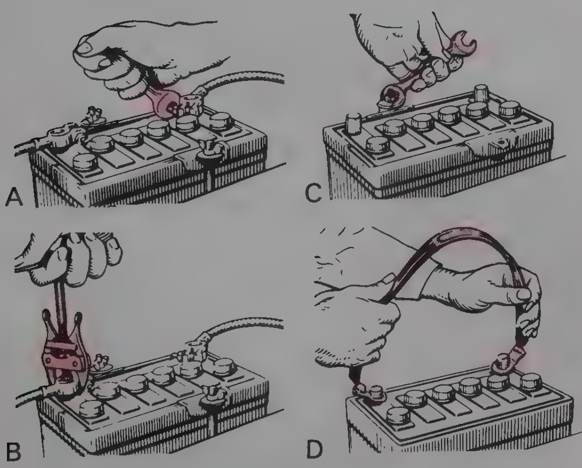


Fig. 23-78. Steps in battery removal. A—Remove battery cable terminals, ground cable first. B—Use puller if terminal is stuck. C—Remove hold-down. D—Attach a battery lift strap.

BATTERY DRAIN—PARASITIC LOADS

Parasitic loads are electronic components that place a small, continuous drain on the battery after the ignition is turned off. The current drain from these loads is extremely small and, therefore, does not discharge the battery, Fig. 23-79A. Nevertheless, parasitic loads must be taken into account when testing for excessive battery drain, Fig. 23-79B.

SEALED BATTERY

Some batteries are completely sealed (other than two small vent holes). They do not require additional water throughout their entire life. Note built-in charge indicator in maintenance-free battery shown in Fig. 23-80.

JUMP STARTING WITH A BOOSTER BATTERY

When a battery has become discharged to the point it will not crank the engine, the engine can be started with a BOOSTER BATTERY.

A booster battery is an additional, properly charged battery of the same voltage. It is connected to the vehicle's discharged battery with two JUMPER CABLES.

Component	**Typical Parasitic**	**Maximum Parasitic**
BCM	3.6	12.4
ECM	5.6	10.0
Radio	3.0	6.0
Regulator	1.4	2.0
ELC	2.0	3.3
CPS	1.6	2.7
Illuminated Entry	1.0	1.0
Theft	0.4	1.0
Auto Door Locks	1.0	1.0
Chime	1.0	1.0
HVAC Power Mod.	1.0	1.0

A

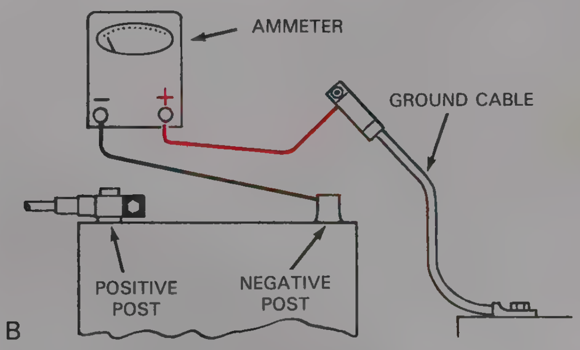


Fig. 23-79. A—Current drain caused by parasitic loads is measured in milliamps (mA). B—An ammeter is used to check for excessive current drain at battery. A small amount of current flow is considered normal.

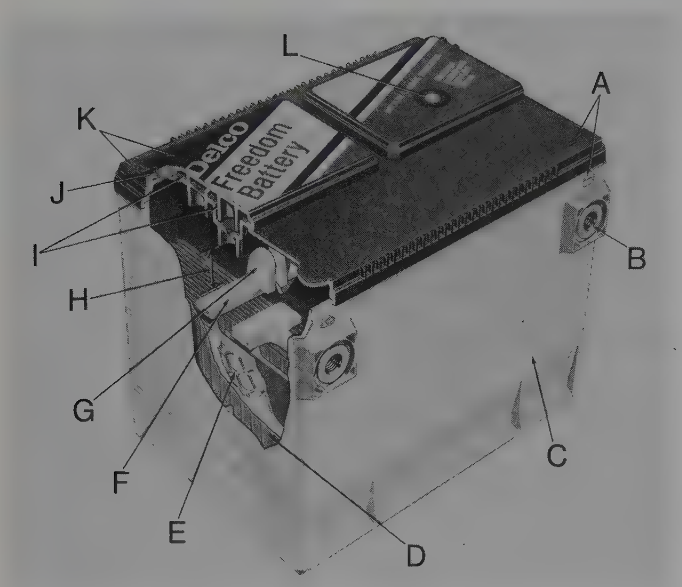


Fig. 23-80. Sealed, maintenance-free battery. A—Molded symbols identify polarity. B—Sealed terminal connections. C—Ribbed polypropylene case. D—Separator envelopes. E—Wrought lead-calcium grids. F—Centered plate straps. G—Extrusion-fusion intercell connections. H—Large electrolyte reservoir. I—Liquid-gas separator. J—Small gas vents with built-in flame arrestors. K—Heat-sealed covers. L—Charge indicator.

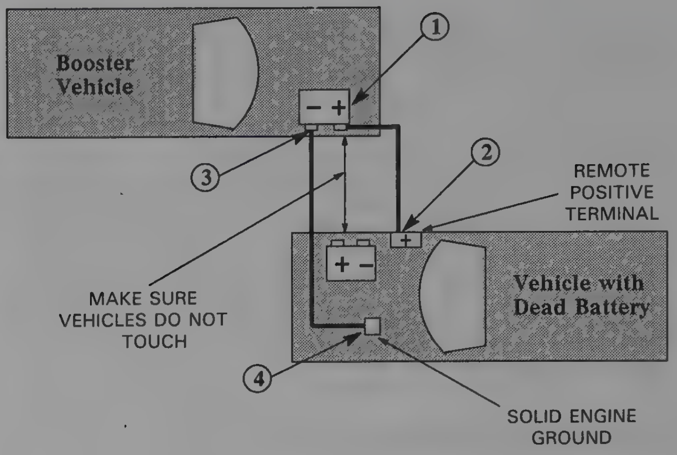


Fig. 23-81. Typical jumper cable connection layout. Circled numbers indicate proper connection sequence. Note the use of a remote positive terminal. (Buick)

WATCH OUT! FOLLOW THESE SAFETY PRECAUTIONS

Jump starting, correctly done, is safe. Ignoring safety precautions can result in an exploded battery, with possible serious injury and vehicle damage. Batteries (even discharged) contain hydrogen gas that, if ignited, will explode, scattering battery parts and acid in all directions. FOLLOW THESE SAFETY PRECAUTIONS:

1. Make certain vehicles are not touching each other.
2. Wear protective glasses, avoid contact with battery electrolyte, and do not lean over battery when making connections.
3. In very cold weather, check for frozen electrolyte or no visible signs of electrolyte. If either condition exists, warm battery until it reaches a temperature of at least 40°F (4.4°C) before attaching booster. This will prevent battery rupture or explosion.
4. Keep open flames or sparks (including cigarettes, pipe, lighter) away from battery.
5. Before connecting jumpers, remove vent caps (unless sealed battery or flameproof cap) from BOTH batteries and cover cell openings with a cloth strip. When finished, dispose of cloth strips as they were exposed to sulphuric acid.
6. Make recommended connections in proper order. Never permit jumper clamps to touch each other. Never connect batteries in series. See Fig. 23-81.
7. Remove metal watchbands, rings, and other jewelry when working on or around batteries. Use proper tools.
8. If electrolyte (sulphuric acid) is splashed on you or the vehicle, FLUSH IMMEDIATELY WITH LOTS OF WATER. A solution of baking soda and water can be poured on clothing to neutralize the acid.
9. When using a portable starting unit, do not exceed 16 volts to prevent starter, battery, or other electrical system damage.

JUMP STARTING—SEQUENCE OF OPERATIONS

CAUTION: Always turn the ignition switch OFF when working with jumper cables. Failure to do so can damage the ECU and other electronic parts. Cellular telephones can also be damaged during jump starting operations. If necessary, disconnect the phone's power lead by unplugging it from the cigarette lighter or removing the power lead fuse. Check with phone manufacturer for specific instructions.

When using jumper cables, it is important to connect them in the proper sequence.

Turn off all switches on both vehicles. Make certain they are not touching. FIRST, connect one jumper clamp to BOOSTER POSITIVE terminal. SECOND, connect other end of same cable to dead battery POSITIVE. THIRD, connect one end of other jumper cable to BOOSTER NEGATIVE. FOURTH, clamp jumper other end to disabled car's ENGINE.

Start engine in booster car (electrical loads off in both cars) and run a few minutes. Start disabled car. When running, disconnect jumper cables in EXACT REVERSE ORDER: Negative jumper from car engine and then from booster negative, positive jumper from discharged battery, and, finally, from booster. NEVER LET CLAMP ENDS TOUCH DURING OPERATION.

CHARGING SYSTEM SERVICE

The alternator-regulator system keeps the battery charged. It also supplies the electrical needs of the various units during engine operation.

Periodic servicing, such as belt tensioning and lubrication, will usually be all that is required for thousands of miles. Many late model AC generators (alternators) use sealed bearings. No lubrication is needed. However, normal wear, part failure, and service incurred damage, may result in system malfunction (overcharge, undercharge) or failure (no charge).

Many problems in the charging system start out as minor problems and gradually become worse. The fact that a problem exists in the charging system may be made known (without conducting tests) in a number of ways. See Figs. 23-82 and 23-83.

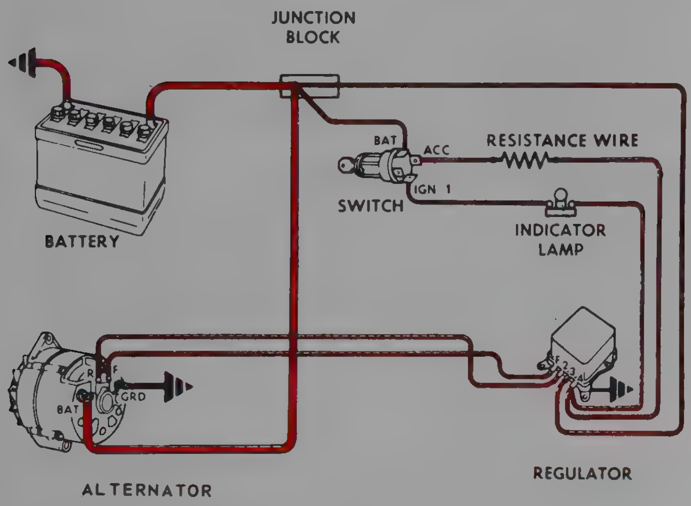


Fig. 23-82. Typical charging circuit. (Buick)

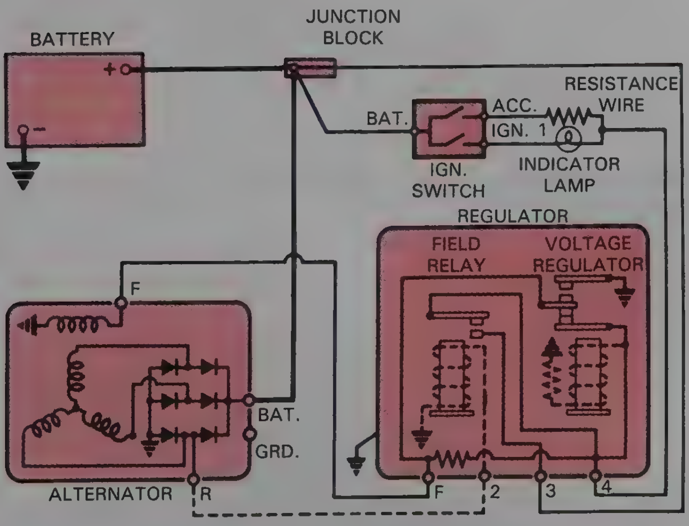


Fig. 23-83. Typical charging circuit—schematic.

CHARGING SYSTEM PROBLEM INDICATIONS—OVERCHARGED BATTERY

Short light bulb life and the frequent need of battery water are two common indications that the system is overcharging. Continued overcharging is damaging to the battery. Unless the problem is corrected, battery service life will be reduced.

PROBLEM INDICATION—UNDERCHARGED BATTERY

Slow cranking, dim headlights, and very infrequent need of battery water indicates an undercharged battery.

PROBLEM INDICATION—AMMETER

System problems are present when the ammeter indicates a high charging rate with a charged battery, a low charging rate with an undercharged battery, or no charge at all.

PROBLEM INDICATION—INDICATOR LIGHT

The charge indicator should light when the key is on—engine not running. It should NOT light when the engine is running. It should NOT light when the key is off. Performance contrary to this indicates system problems.

PROBLEM INDICATION—NOISY ALTERNATOR

An alternator in sound mechanical condition will run quietly. A whining noise at idle speed can indicate a faulty diode. A noisy condition in the unit can mean a diode is open and is creating an electrical unbalance.

Belt squeal can be caused from a loose or glazed belt. Dry or worn bearings and loose pulleys can cause clicking, squealing, and growling sounds in both types of generators.

QUICK INITIAL CHECK CAN SAVE TIME AND TROUBLE

Before starting a series of time-consuming tests or, worse yet, removing parts for repair or replacement, give the system a quick initial inspection. Such a check will often turn up the source of the trouble.

Check the drive belt condition and check for proper tension. Inspect all connections. Examine wires for signs of burning or fraying. Check the regulator and alternator for evidence of physical damage.

SOUND BATTERY IS A MUST

A worn out or badly sulphated battery will produce numerous problems that cannot be corrected until the battery is replaced. ALWAYS CHECK BATTERY CONDITION BEFORE CONDEMNING OTHER PARTS OF THE SYSTEM. A FULLY CHARGED BATTERY IS A MUST FOR CONDUCTING ACCURATE SYSTEMS TESTS.

UNITS THAT MAY CAUSE CHARGING PROBLEMS

Charging system malfunctions can be traced to either the battery, generator, regulator, or the wiring. Troubles may involve one unit or in some cases, all units.

PROBLEM MUST BE SOLVED

Never replace a defective unit without determining what CAUSED the failure. If the failure was brought on by some other unit or units, they, too, must be repaired or replaced or the new unit will fail.

ALTERNATOR SERVICE PRECAUTIONS

There are a number of important precautions that are VITAL when working on the alternator charging system. Failure to observe these rules can result in serious system damage. Learn and observe all the following rules:

1. When installing the battery, make sure the polarity is correct by grounding the battery as specified.
2. When using a booster battery, connect it in parallel—pos. to pos. and neg. to neg.
3. Disconnect battery cables when charging the battery. Never use a fast charger as a booster to help in cranking.
4. When soldering to a rectifier (diode) lead, always grasp the lead with a pair of pliers—between the joint and the rectifier body. The pliers will act as a heat dam or sink and protect the rectifier from overheating.
5. Never connect a "hot" wire to regulator field.
6. Never try to polarize an alternator.
7. Never operate alternator OPEN circuit (voltage regulator or generator lead disconnected). This will allow alternator to build up very high voltage that can damage diodes and be VERY DANGEROUS TO ANYONE TOUCHING THE ALTERNATOR BATTERY TERMINAL.
8. Unless specified, never ground the field circuit, either at the generator or regulator.
9. Remove battery ground lead before removing or replacing system wires or units. This is also necessary before connecting test instruments other than a voltmeter. An accidental short at the generator, regulator, etc., can damage both units and wiring.
10. When adjusting regulator, use an insulated tool to prevent accidental grounding.
11. Do not ground AC generator output terminal. Do not ground regulator terminals.
12. Ignition switch must be OFF when removing or installing the regulator cover.
13. Disconnect connector plug from regulator BEFORE removing mount screws. Pulling connector from an ungrounded regulator can ruin it.
14. Use correct alternator.
15. Use correct regulator.

PROBLEM INDICATIONS

Charging system problems are discussed earier in this chapter.

Give the alternator system the same quick check for wire condition, terminal tightness, and loose drive belt. Check battery for condition as well as for state of charge. Clean and tighten battery cable terminals. Replace faulty battery. Charge discharged but sound battery. THIS IS VERY IMPORTANT AS A DISCHARGED OR FAULTY BATTERY CAN PREVENT ACCURATE TESTING OF THE SYSTEM.

DISCONNECT BATTERY CABLE

Always disconnect the battery ground cable before making or breaking any test connection or removing any system units or wire connections. Keep the ignition key OFF until ready to start the engine. Failure to follow this procedure can result in serious system damage.

CHECK ALTERNATOR CHARGING CIRCUIT FOR EXCESSIVE RESISTANCE

The charging system cannot function properly when excessive resistance is present. When system malfunctions are evident and if the quick check does not reveal the exact cause, check the system resistance before conducting more exhaustive tests. When high resistance is found, replace the wire if faulty or clean and tighten connections.

FIELD CIRCUIT RESISTANCE TEST—ALTERNATOR SYSTEM

Connect test instrument as instructed by the manufacturer.

For the setup shown in Fig. 23-84, disconnect the slip-on connector from one end of the ballast resistor. Turn on the ignition switch, accessories off, doors and trunk closed, and read the voltmeter. A reading in excess of 0.55 volt indicates high resistance.

If excessive resistance is present, start moving the negative voltmeter lead along the circuit. Check at each connection. Move wire and apply a small twisting force

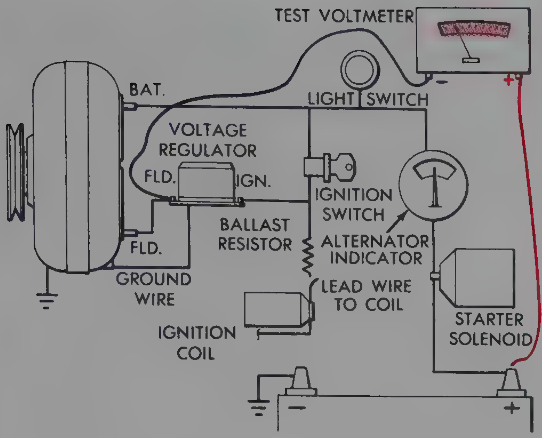

TEST VOLTMETER
BAT.
LIGHT SWITCH
VOLTAGE REGULATOR
FLD.
IGN.
IGNITION SWITCH
BALLAST RESISTOR
ALTERNATOR INDICATOR
FLD.
GROUND WIRE
LEAD WIRE TO COIL
IGNITION COIL
STARTER SOLENOID
+
−
−
+

Fig. 23-84. Testing alternator field circuit resistance. (Dodge)

to each terminal while watching meter. When a quick voltage drop is found, clean and tighten that connection.

ALTERNATOR-TO-BATTERY POSITIVE TERMINAL RESISTANCE TEST

One hookup is illustrated in Fig. 23-85. For this setup, turn off all accessories. Close battery post adapter switch and start engine. When started, open switch.

Bring engine speed up to 2000 rpm. Produce an ammeter reading of 20 amps. by adjusting the field rheostat. With engine at 2000 rpm, ammeter reading 20 amps., the voltmeter reading should not exceed 0.3 volts.

ALTERNATOR-TO-BATTERY GROUND TERMINAL RESISTANCE TEST

For the test hookup shown in Fig. 23-86, turn off all accessories. Close battery adapter switch and start engine. Open adapter switch. Bring engine speed to 2000 rpm. Adjust ammeter reading to 20 amps. by moving field rheostat. Voltage reading should not exceed 0.1 volt.

CHECK ALTERNATOR OUTPUT

One method of checking alternator output is pictured in Fig. 23-87. To conduct this test, make connections as indicated. Field rheostat must be OFF for start of test. Lights and accessories OFF.

Close adapter switch and start engine. Open adapter switch. Run engine up to 2000 rpm.

Adjust field rheostat clockwise to give a 15 volt reading on the voltmeter. Turn master control clockwise to alter reading to 11-12 volts. Turn field rheostat fully clockwise. Then turn master control counterclockwise to give a reading of 15 volts. Note ammeter reading. Add about 2 amps. (for standard ignition) or

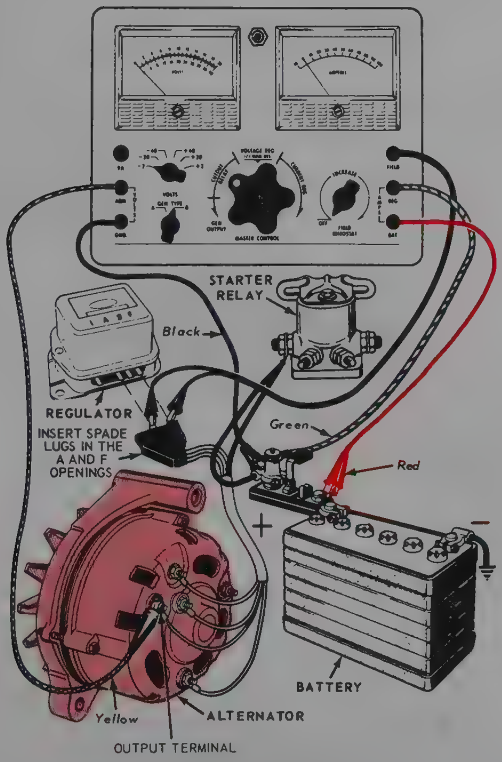

STARTER RELAY
Black
REGULATOR
INSERT SPADE LUGS IN THE A AND F OPENINGS
Green
Red
+
−
BATTERY
Yellow
ALTERNATOR
OUTPUT TERMINAL

Fig. 23-85. Alternator-to-battery positive terminal resistance test. (Lincoln)

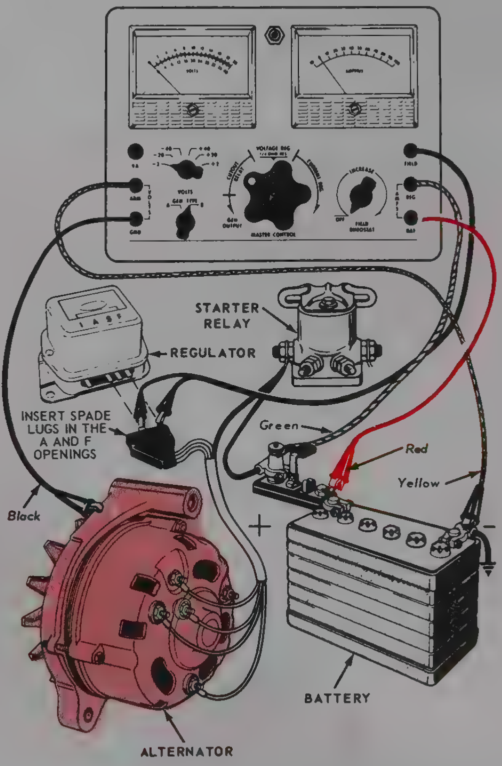

STARTER RELAY
REGULATOR
INSERT SPADE LUGS IN THE A AND F OPENINGS
Green
Red
Yellow
Black
+
−
BATTERY
ALTERNATOR

Fig. 23-86. Alternator-to-battery ground terminal resistance test.

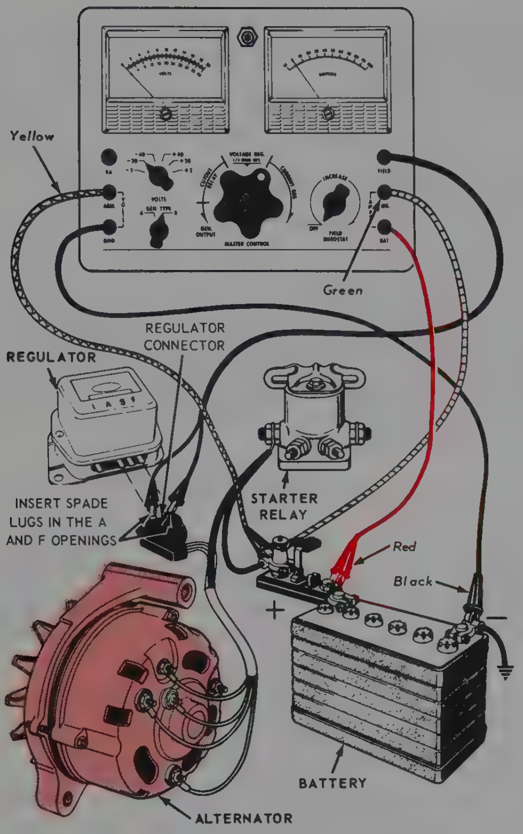


Fig. 23-87. Testing alternator output.

6 amps. (for transistor ignition). If necessary, engine rpm can be increased to 2900 to produce rated output.

A shorted diode (will usually whine at idle) generally will reduce output 10 to 15 amps. An open diode will reduce output 2 to 8 amps.

DIODES CAUSE A LARGE PERCENTAGE OF ALTERNATOR PROBLEMS

Quite often the diodes are responsible for charging system problems. Carelessness in battery charging, use of booster batteries, and inexperienced servicing can quickly ruin the diodes. When the alternator is found defective, always test the diodes.

TESTING DIODES

Some alternators require disassembly in order to test the diodes. Others do not. Follow manufacturer's instructions.

Diodes may be tested by using a special diode tester, by using an ohmmeter, or by using a 12-volt test lamp. DO NOT USE A 120-VOLT TEST LAMP. If a 12-volt test lamp is selected, use a No. 67 bulb. Both the ohmmeter and test lamp methods require disconnecting the diode leads.

When a test lamp is used, one prod should be placed on the rectifier lead and the other on the outer case or heat sink. Make sure the connections are good. Reverse the prods. If the diode is GOOD, the lamp will light with the prods in one position but will NOT light in the other. An OPEN diode will fail to light the lamp in either direction. A SHORTED diode will light the lamp in both directions.

The ohmmeter is used much as the test lamp. Place one test prod on the diode case. Place the other test prod on the diode lead. Again, make sure the connections are good.

When the diode is GOOD, a high reading will be given with the test prods in one position and a low reading in the other. An OPEN diode will give high readings in both positions. A SHORTED diode will give low readings in both directions.

Prod tips must be sharp. Make certain they penetrate any varnish coating present on the terminals. Test ALL diodes. Positive diodes will test the same as negative diodes, the only difference being that the lamp will light in the opposite prod position. See Fig. 23-88.

A faulty capacitor will often be discovered when the diodes test OPEN or SHORTED.

REMOVING AND REPLACING DIODES

NEVER POUND ON A DIODE IN AN ATTEMPT TO REMOVE OR REPLACE IT. Use a press and suitable tools. Fig. 23-89 shows a diode being pressed into place in the heat sink. Note how the sink is supported. The pressing tool must bear against the OUTER edge of the diode case.

When soldering diode leads, always grip the lead, between the diode and soldered area, with a pair of pliers. The pliers will protect the diode from excessive heat. See Fig. 23-90.

Some alternators use three diodes (sometimes called a "diode trio"). They are all held together in a group and enclosed in a dielectric (nonconducting) material. These must be serviced as a unit. See Fig. 23-91.

ALTERNATOR DISASSEMBLY

Specific disassembly varies with the design of the alternator. The following steps are typical of many

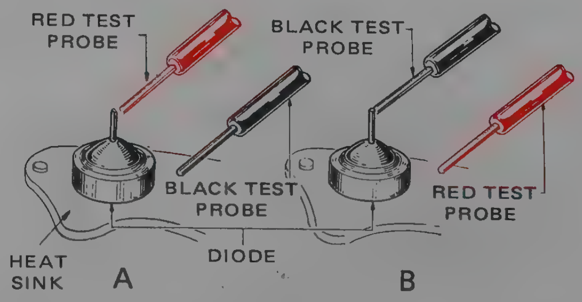


Fig. 23-88. Testing a diode. A—First test. B—Second test. Note how leads are reversed in B. Test light should come on in one test and go out in other if diode is good. (Nissan)

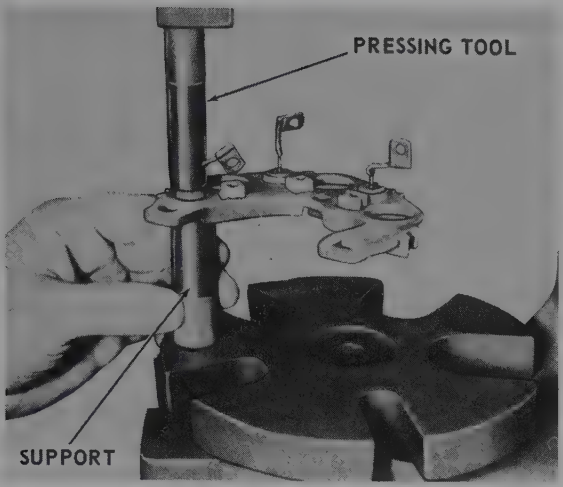

PRESSING TOOL
SUPPORT

Fig. 23-89. Pressing diodes into place in heat sink. (G.M.C.)

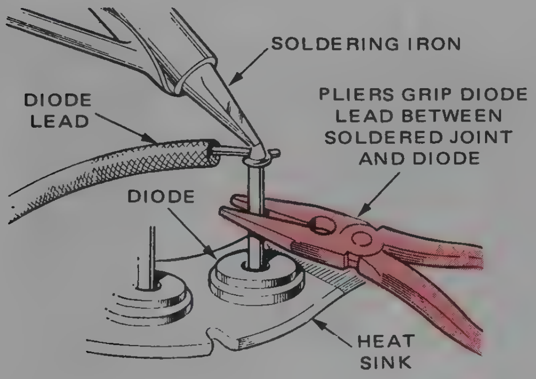

SOLDERING IRON
DIODE LEAD
PLIERS GRIP DIODE LEAD BETWEEN SOLDERED JOINT AND DIODE
DIODE
HEAT SINK

Fig. 23-90. Using pliers as a heat dam, or heat sink, to protect diode from excessive heat during soldering. (British Leyland)

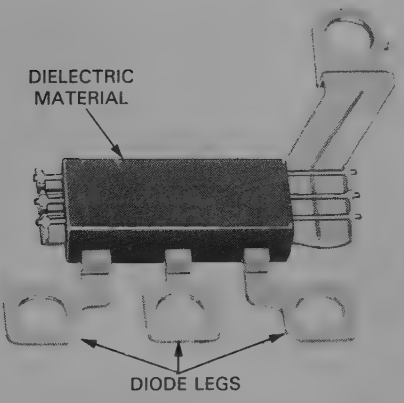

DIELECTRIC MATERIAL
DIODE LEGS

Fig. 23-91. A typical diode "trio." Three diodes are held within a molded dielectric material. (Deere & Co.)

types. Remove the pulley nut. Using a suitable puller, remove the pulley. Remove the through-bolts. Pry the slip ring end frame and drive end frame apart. Separate the units. The units should be marked with a scriber before disassembly.

On some models, it is advisable to remove the brush assembly before dismantling the alternator. See Fig. 23-92.

When needed, use pullers to remove end plates and bearings. A cutaway view of a typical alternator is shown in Fig. 23-93.

Clean all parts except rotor, stator, slip ring, and brush assemblies in solvent. Wipe with clean cloth. If bearings are of the sealed type, do not place in solvent.

Where applicable, clean and inspect bearings. If of sealed design, inspect for wear, roughness, and loss or hardening of lubricant. Pack bearings with high temperature bearing grease where required.

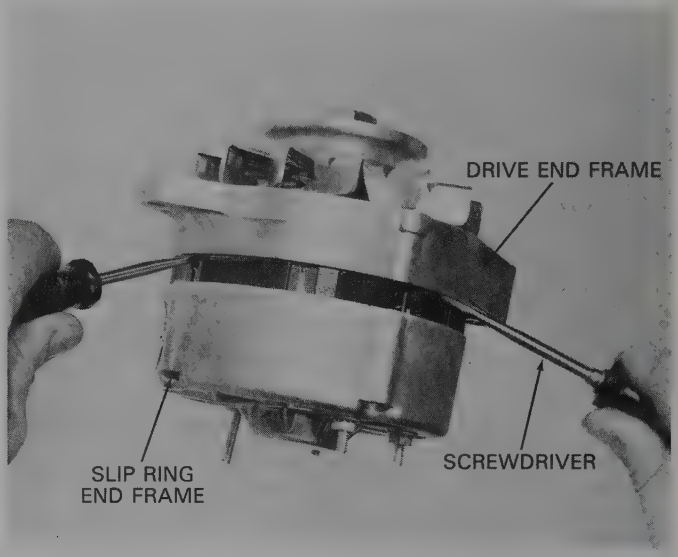

DRIVE END FRAME
SLIP RING END FRAME
SCREWDRIVER

Fig. 23-92. Separating alternator drive and slip ring and frames. (AMC)

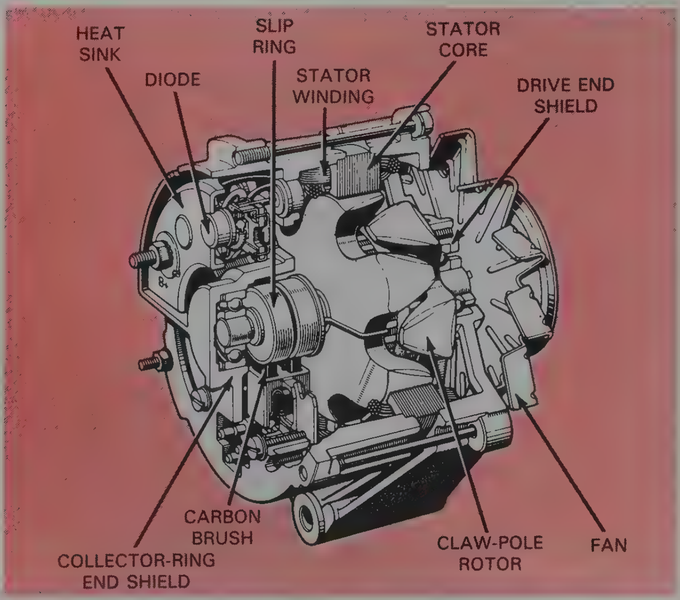

HEAT SINK
SLIP RING
STATOR CORE
DIODE
STATOR WINDING
DRIVE END SHIELD
CARBON BRUSH
COLLECTOR-RING END SHIELD
CLAW-POLE ROTOR
FAN

Fig. 23-93. Typical alternator construction. (American Motors)

CHECK BRUSHES

Brushes must be absolutely free of any oil or grease. If the brushes come in contact with grease during alternator disassembly, clean at once with trichlorethylene or similar cleaner. During an overhaul, it is good practice to replace the brushes regardless of how much wear they show. Check brush springs.

TEST ROTOR WINDINGS FOR OPENS, GROUNDS, AND SHORTS

Use an ohmmeter to check the rotor for grounds, opens, and shorts.

To check for grounds, place one ohmmeter lead on one slip ring and the other on the shaft, Fig. 23-94. If the ohmmeter gives a low reading, the windings are grounded. A test lamp may also be used for this test. The lamp will light if a ground is present.

To test for opens, Fig. 23-94, place one ohmmeter lead on each slip ring. If the windings are open, a high (infinite) reading will occur. If a test lamp is used, lamp will not light if the windings are open.

To check for shorts, attach an ohmmeter lead to each slip ring, Fig. 23-94. Check ohmmeter reading against specifications. If below specifications, windings are shorted.

When using a test light, never place the prods on that portion of the slip ring contacted by the brush or on the rotor shaft contacted by the bearing. To do so could pit the surface from arcing.

INSPECT SLIP RINGS

The slip rings must be smooth and round. If they are dirty, they should be cleaned by turning the rotor while holding 400 grain polishing cloth against the slip rings. DO NOT USE EMERY CLOTH.

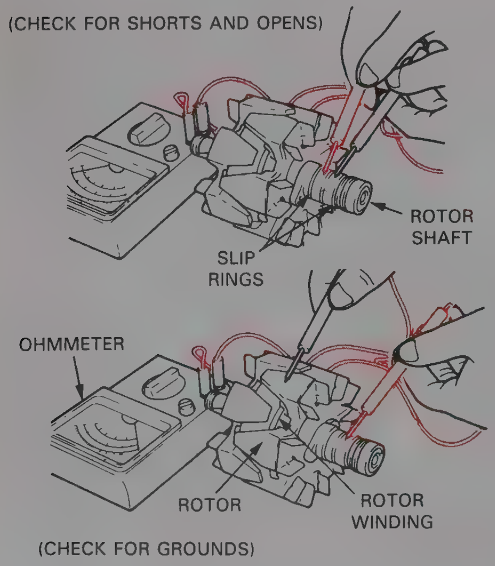


Fig. 23-94. Testing alternator rotor for shorts, opens, and grounds. (Plymouth)

If the rings are scored or out-of-round, they must be turned down until true. Remove as little material as possible. Polish with 400 grain polishing cloth. See Fig. 23-95.

Check the rotor shaft bearing areas for signs of wear, scoring, and other problems.

TEST STATOR WINDINGS FOR OPENS, GROUNDS, AND SHORTS

To check the stator windings for grounds, connect an ohmmeter or test lamp as shown in Fig. 23-96A. This one connection will check all three legs of the windings. The lamp SHOULD NOT LIGHT. The ohmmeter will show a high reading. If the light comes on,

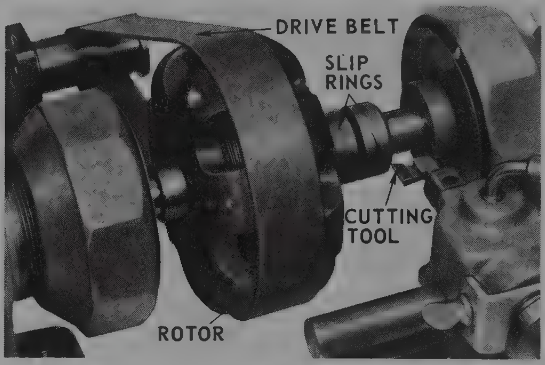


Fig. 23-95. Turning the slip rings on an alternator rotor. (Trucut)

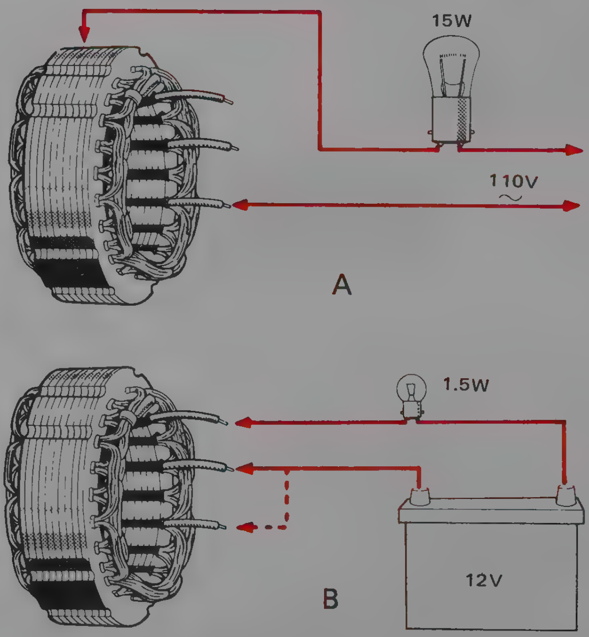


Fig. 23-96. Testing stator windings. A—Testing for grounds. B—Testing for opens. (British Leyland)

or if the ohmmeter shows a low reading, the circuit is grounded.

To test for opens, connect a test lamp as shown in Fig. 23-96B. The lamp SHOULD LIGHT. An ohmmeter should show specified resistance. If the lamp does not light, or if the ohmmeter shows an infinite resistance, the windings are open.

The check for winding shorts is sometimes difficult and requires more test equipment. Visually inspect the windings for signs of overheating. You may assume that when all other electrical checks are OK and when all components have checked out and the alternatorr still does not produce its specified output, the stator windings are shorted.

CAPACITOR TEST

The capacitor may be tested by disconnecting and then placing an ohmmeter across the leads. An infinite reading indicates good condition. A low reading indicates a defective condenser. To test condenser capacity in microfarads, use a condenser tester.

ALTERNATOR ASSEMBLY

Where specified by the manufacturer, bearings must be packed with grease.

Assemble in reverse order of disassembly. Work carefully. When parts are a press fit, use a press. Align scribe marks. Torque pulley retaining nut. Never clamp rotor to hold while torquing pulley nut. To do so may deform the rotor. Clamp the pulley.

Some alternator brush assembly designs permit the use of a pin to hold the brushes in the holder during assembly. Some require hooking the brush leads over a section of the brush holder for installation. Another type uses simple brush holders that permit installation after the alternator is assembled.

If a brush holder pin is used, or if the leads are hooked, remove pin or straighten leads after assembly. See Figs. 23-97 and 23-98.

Make sure all parts are correctly located. Spin the rotor to check for free operation.

When assembling the alternator to the engine, adjust belt tension by prying on the heavy drive end frame edge. Never pry against the center or at the slip ring frame end.

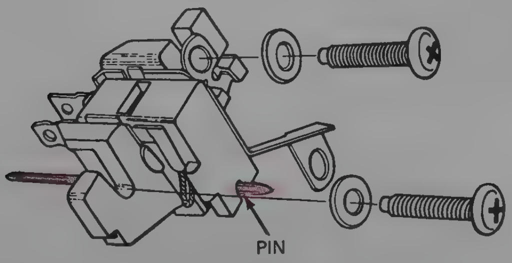


Fig. 23-97. Pin holds brushes in holder for easy assembly. (Pontiac)

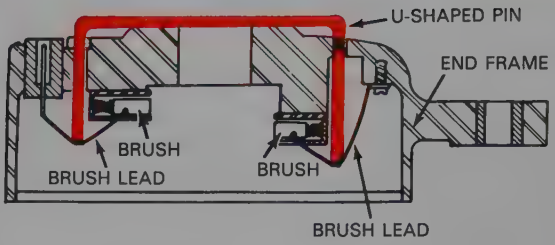


Fig. 23-98. These brushes are kept retracted to allow installation of rotor by using a stiff, U-shaped pin. (Autolite)

Connect all leads to alternator. Connect battery leads. Start engine and test alternator.

ELECTRONIC VOLTAGE REGULATOR SERVICE

Many vehicles are equipped with electronic voltage regulators. These units regulate the alternator's output using transistors, diodes, resistors, and capacitors, Fig. 23-99. Although electronic voltage regulators handle heavy loads and provide excellent service, they can still malfunction under certain conditions.

WHEN TESTING OR ADJUSTING ALTERNATOR VOLTAGE REGULATORS, OBSERVE ALL THE CAUTIONS REGARDING ALTERNATOR SYSTEM SERVICE.

Most manufacturers recommend a regulator bypass test to check regulator operation. This test is performed by monitoring changes in battery voltage while bypassing the regulator. Some alternators are equipped with special grounding tabs that can be used to bypass the voltage regulator. Many bypass tests are performed by attaching a jumper wire between terminals on the alternator or regulator. Consult an appropriate service

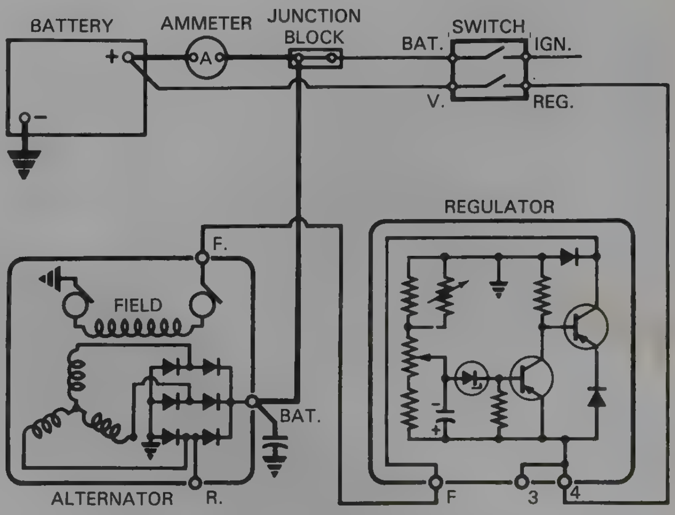


Fig. 23-99. A schematic diagram of a charging system containing an electronic voltage regulator. Note the absence of mechanical parts. (Pontiac)

manual for proper testing procedures.

When the regulator is bypassed, the alternator will produce its maximum output voltage. If battery voltage increases during a bypass test, the regulator is probably faulty. The regulator is working correctly if battery voltage remains constant during the test. If battery voltage is below 14 volts during a regulator bypass test, the alternator should be checked for proper operation.

Most electronic voltage regulators cannot be repaired. If they are faulty, they must be replaced. Some regulators are adjustable. If battery voltage is not within the manufacturer's specifications, the regulator can be adjusted to obtain the correct charging voltage, Fig. 23-100.

ELECTROMAGNETIC VOLTAGE REGULATOR SERVICE

Many older vehicles are equipped with electromagnetic voltage regulators. These units use electric coils and contact points to regulate alternator (generator) output. Electromagnetic regulators are not as reliable as electronic regulators and require periodic adjustment. Always refer to an appropriate service manual before servicing these regulators. Testing procedures and adjustment specifications can vary among manufacturers.

CHARGE INDICATOR LIGHT

If the indicator lamp fails to light when the ignition key is turned on (engine stopped), check for a burned out bulb, corrosion or looseness in the lamp socket, and loose, corroded, or open connections in the circuit. If the indicator light stays on when the ignition key is turned off, check for a shorted positive diode in the alternator.

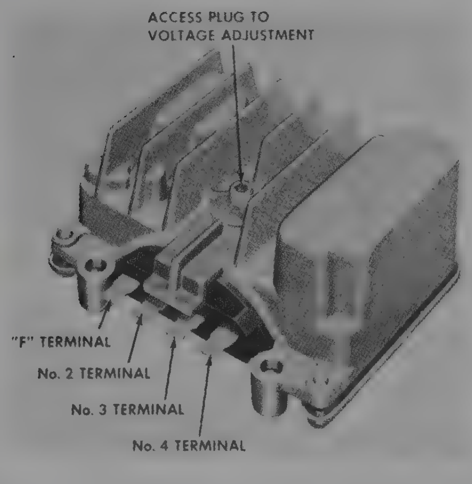


Fig. 23-100. This electronic regulator is adjusted by removing access plug and turning voltage adjustment screw. Turn clockwise to increase voltage setting. (Pontiac)

When the engine is idling, the indicator light should go out. If it continues to burn, check for slow idle speed. If this does not correct the problem, check the generator drive belt adjustment, field relay operation, and alternator output. Conduct other system tests as required to pinpoint the bad unit or units.

COMPUTERIZED CHARGING SYSTEM

In many vehicles, an on-board computer controls the current to the alternator's field terminal. This arrangement eliminates the need for a voltage regulator. Most computerized charging systems have self-diagnostic capabilities. When the computer detects a malfunction in the charging system, it stores a trouble code in its memory and activates the check engine light. A typical computerized charging system is illustrated in Fig. 23-101.

For more information on trouble codes and computerized systems, see Chapter 24.

STARTING SYSTEM SERVICE

The starting system consists of the battery, starter motor, solenoid, ignition switch, neutral safety switch, and related wiring, Fig. 23-102.

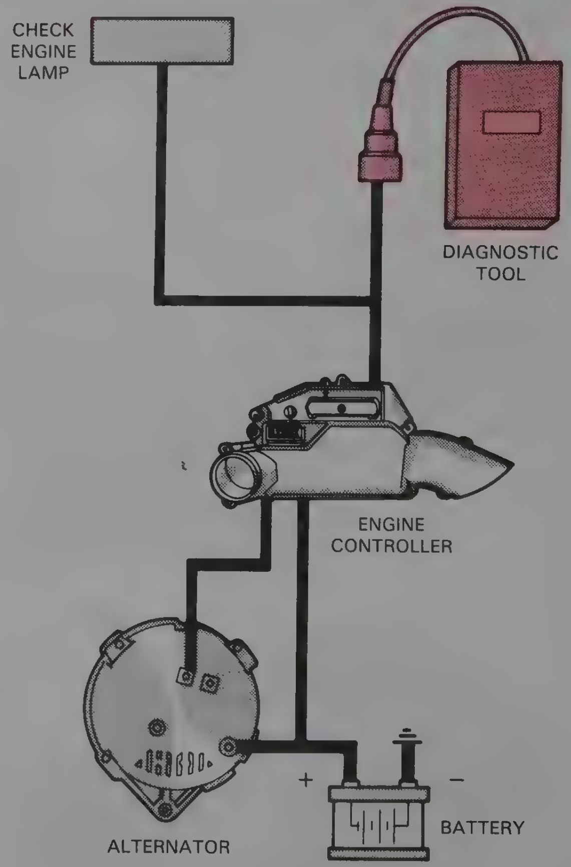


Fig. 23-101. Typical computerized charging system. Note hookup for diagnostic tool. (Chevrolet)

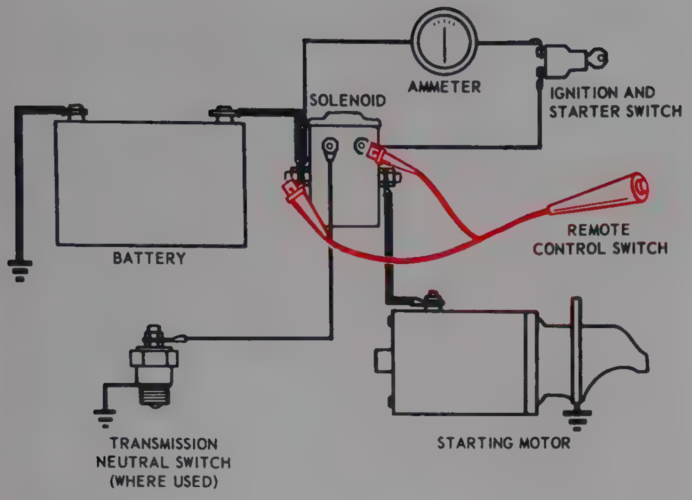

AMMETER
SOLENOID
IGNITION AND STARTER SWITCH
BATTERY
REMOTE CONTROL SWITCH
TRANSMISSION NEUTRAL SWITCH (WHERE USED)
STARTING MOTOR

Fig. 23-102. Component parts of starting system or circuit. Note remote starting (control) switch in place. (Ignition Mfg's Inst.)

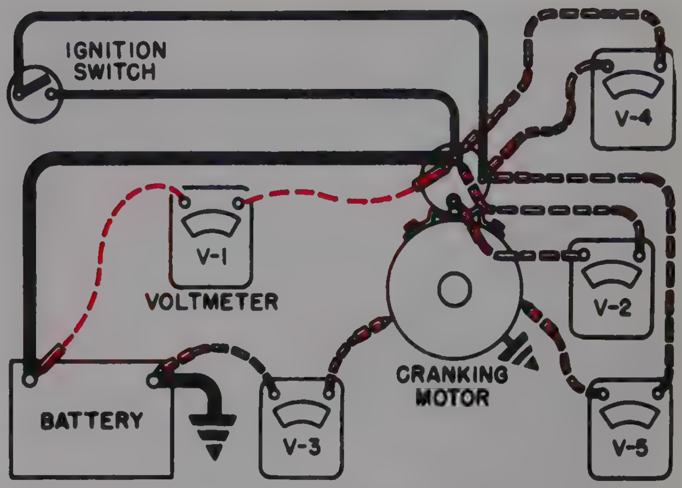


Fig. 23-103 Voltmeter connections for checking starting circuit resistance. (Oldsmobile)

A remote control starter switch is shown in place. This is used to energize the starter without getting into the car to operate the regular starter switch. The method of attaching this remote starter varies according to circuit design.

ALWAYS CHECK BATTERY FIRST

Many complaints of poor starter performance are traced to a discharged or defective battery. Give the battery a thorough check. (See section on battery service.) REMEMBER THAT PROPER STARTER MOTOR PERFORMANCE DEMANDS A CHARGED, SOUND BATTERY.

CHECK CIRCUIT FOR VOLTAGE DROP

Give the starter circuit wiring a quick visual check. Remove and clean corroded battery terminals. Clean and tighten other loose, burned, or corroded connections. Look for frayed, broken, or shorted wires.

Following the visual check for sources of high resistance, the circuit should be tested for excessive resistance. Use an accurate LOW READING voltmeter.

Make the voltmeter connections as illustrated in Fig. 23-103. Remove the ignition coil high tension lead from the distributor. GROUND it or ground the primary DISTRIBUTOR terminal of the coil. The technique must be compatible with the type of ignition system—standard or transistorized.

Crank the engine with the voltmeter leads connected across the battery positive post and the BAT terminal of the starter solenoid—V-1 connection, Fig. 23-103. Voltage reading (drop) should not exceed 0.2 volt.

Make voltmeter V-2 connections across BAT terminal and MOTOR terminal of the solenoid. Crank engine. Drop should not exceed 0.2 volt.

Place voltmeter leads in V-3 position across battery negative post and the starter motor frame. Crank engine. Drop should not exceed 0.2 volt.

DO NOT OPERATE THE STARTER MOTOR FOR EXTENDED PERIODS AS IT WILL BE DAMAGED FROM OVERHEATING. OPERATE FOR A MAXIMUM OF 20 OR 30 SECONDS. THEN ALLOW IT TO COOL FOR A COUPLE OF MINUTES BEFORE RESUMING CRANKING.

The V-4, Fig. 23-103, position (across BAT terminal and SWITCH terminal on solenoid) is used to detect excessive voltage drop in the solenoid circuit. Voltage drop (engine cranking) should not exceed 2.5 volt.

The V-5 connection (across SWITCH terminal of solenoid and starter frame) will measure the voltage available at the switch terminal. If voltage at the switch meets specifications and if the solenoid does not pull in, remove the starter for further testing.

THE VOLTAGE DROPS USED HERE ARE GENERAL AVERAGES. ALWAYS USE THE MANUFACTURER'S SPECIFICATIONS FOR THE CAR AT HAND.

SOLENOIDS, RELAYS, AND SWITCHES

In the event of starter circuit difficulties, do not overlook the relay, solenoid, and switches. These units will occasionally fail. Check each one for correct operation. This can be done by bypassing a switch with a jumper wire or by replacing a suspected relay or solenoid with one known to be good. The use of test instruments to check available voltage, voltage drop, and other values can also be helpful.

Do not forget the safety lockout switch used on cars with automatic transmissions. In addition to mechanical failure, it can also get out of adjustment.

STARTER LOAD TEST

The starter load test will indicate the current draw in amperes during cranking. It will provide an indication of starter motor condition. Excessive engine friction (new rings, bearings, or pistons fitted too tight) will also be disclosed by this test.

Instruments for the LOAD test may be connected as illustrated in Fig. 23-104.

Ground the coil secondary lead, the coil distributor lead, or the ignition control module to prevent the engine from starting.

Turn carbon pile to the FULL RESISTANCE position. While cranking the engine, note the EXACT voltmeter reading.

When finished cranking, slowly reduce the carbon pile resistance until the voltmeter reading is the same as the reading noted during cranking. At this point, the ammeter will indicate the starter current draw during cranking. Compare ammeter reading with manufacturer's specifications.

STARTER NO-LOAD TEST

Remove starter from engine. DISCONNECT BATTERY GROUND STRAP FIRST. With the test connections pictured in Fig. 23-105, adjust the load control (rheostat) to the extreme clockwise setting. This will prevent any current flow through the ammeter.

Hook the starter up as shown. While the starter is operating, note the EXACT voltmeter reading. Disconnect the starter and back off the load control until the voltmeter reading corresponds to that noted during starter no-load operation. At this point, the ammeter reading will indicate the no-load current draw.

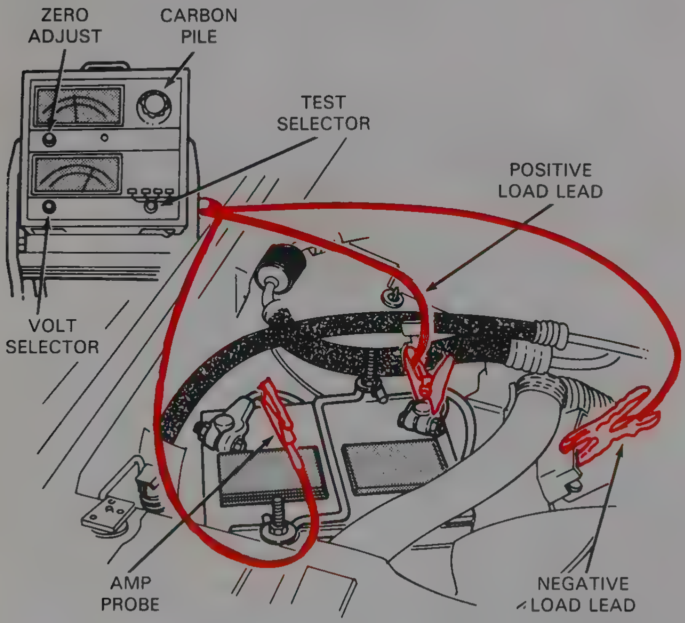

ZERO ADJUST
CARBON PILE
TEST SELECTOR
POSITIVE LOAD LEAD
VOLT SELECTOR
AMP PROBE
NEGATIVE LOAD LEAD

Fig. 23-104. Starter load test connections.

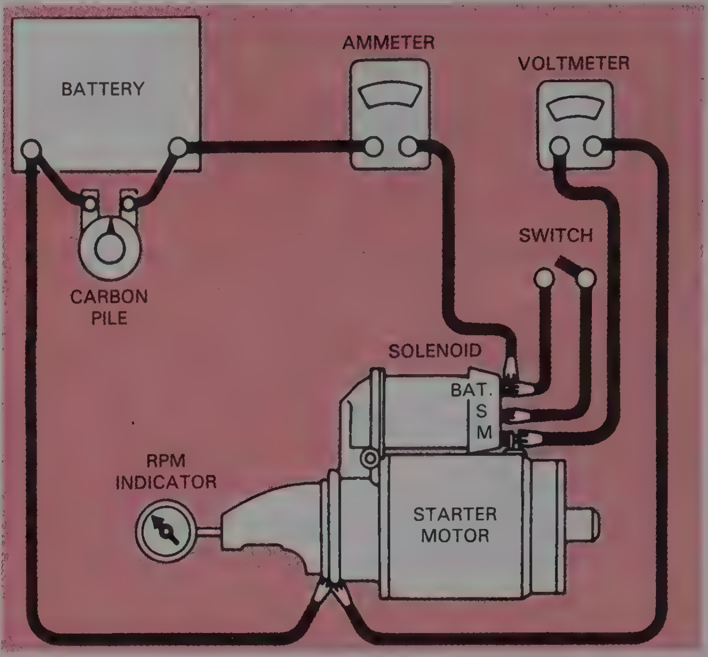

BATTERY
AMMETER
VOLTMETER
SWITCH
CARBON PILE
SOLENOID
BAT.
S
M
RPM INDICATOR
STARTER MOTOR

Fig. 23-105. One starter no-load test hookup.

Secure the starter before making no-load connections. Violent starting torque and extreme no-load rpm can make the starter dangerous.

A tachometer may also be attached to the starter to check no-load rpm. Check current draw and rpm against specifications.

Some manufacturers give test specifications for no-load operation that require a specific voltage be applied to the starter. Current draw at this EXACT voltage must be measured.

STALL TORQUE (LOCKED ARMATURE) TEST

The stall torque test will indicate both starter torque and current draw at a specified voltage. A typical test setup is illustrated in Fig. 23-106.

To conduct the test, the starter is attached to a test stand and the pinion is secured by a special brake or torque arm. The switch is closed and the carbon pile rheostat adjusted to apply the specified voltage to the starter. Current draw will be inicated on the ammeter.

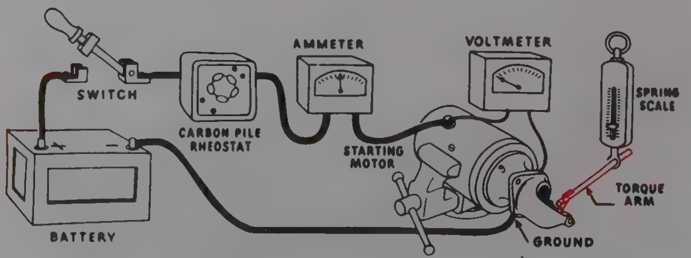

SWITCH
CARBON PILE RHEOSTAT
AMMETER
VOLTMETER
STARTING MOTOR
SPRING SCALE
TORQUE ARM
BATTERY
GROUND

Fig. 23-106. Stall torque test. Note torque arm and scale.

Torque, in foot-pounds, will show on the scale. Make this test as quickly as possible to avoid overheating the starter.

The stall torque and no-load tests will bring to light such problems as a dragging armature, shorted or open windings, frozen bearings, dirty commutator, and poor connections.

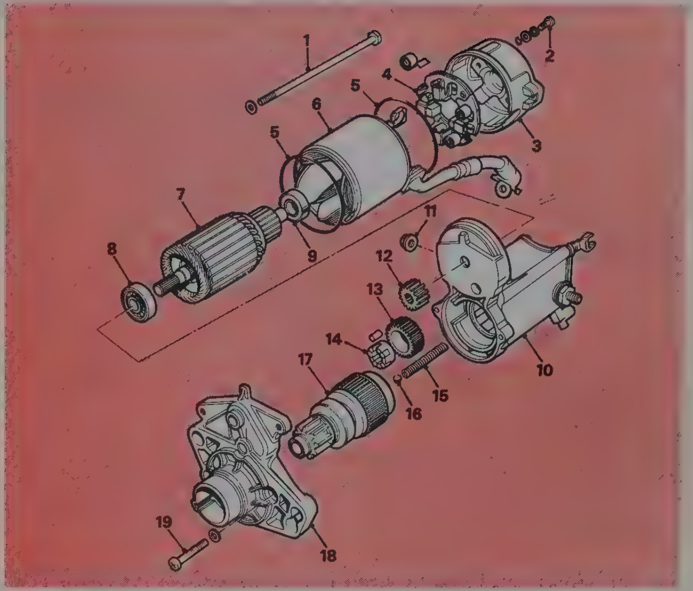
If the starter fails to meet specifications, it must be dismantled and thoroughly checked.

STARTER DISASSEMBLY

Disassemble the starter carefully. Note the location of all parts. Scribe pinion housing-to-frame and end plate-to-frame. This will assist in correct alignment during reassembly (starters are generally equipped with a locating dowel to guarantee proper alignment). If a vise is used to support the starter during disassembly—DO NOT CLAMP TIGHTLY. In some cases it is necessary to unsolder a lead to facilitate part removal.

A cutaway view of a typical solenoid-actuated, overrunning clutch drive type starter is shown in Fig. 23-107. Fig. 23-108 shows an exploded view of a starter assembly.

A somewhat different starter drive actuating setup is pictured in Fig. 23-109. This arrangement employs


1
2
4
5
3
6
5
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12
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14
17
10
15
16
19
18

Fig. 23-108. One type of starter employing a solenoid-actuated overruning clutch drive. 1—Motor through bolt. 2—Brush holder screw. 3—End cover. 4—Brush holder. 5—Ring seal. 6—Yoke. 7—Armature. 8—Gear housing bearing. 9—End cover bearing. 10—Solenoid housing. 11—Terminal nut. 12—Pinion gear. 13—Idler gear. 14—Roller bearings and cage. 15—Plunger spring. 16—Steel ball. 17—Overrunning clutch. 18—Gear housing cover. 19—Solenoid screw. (Sterling)

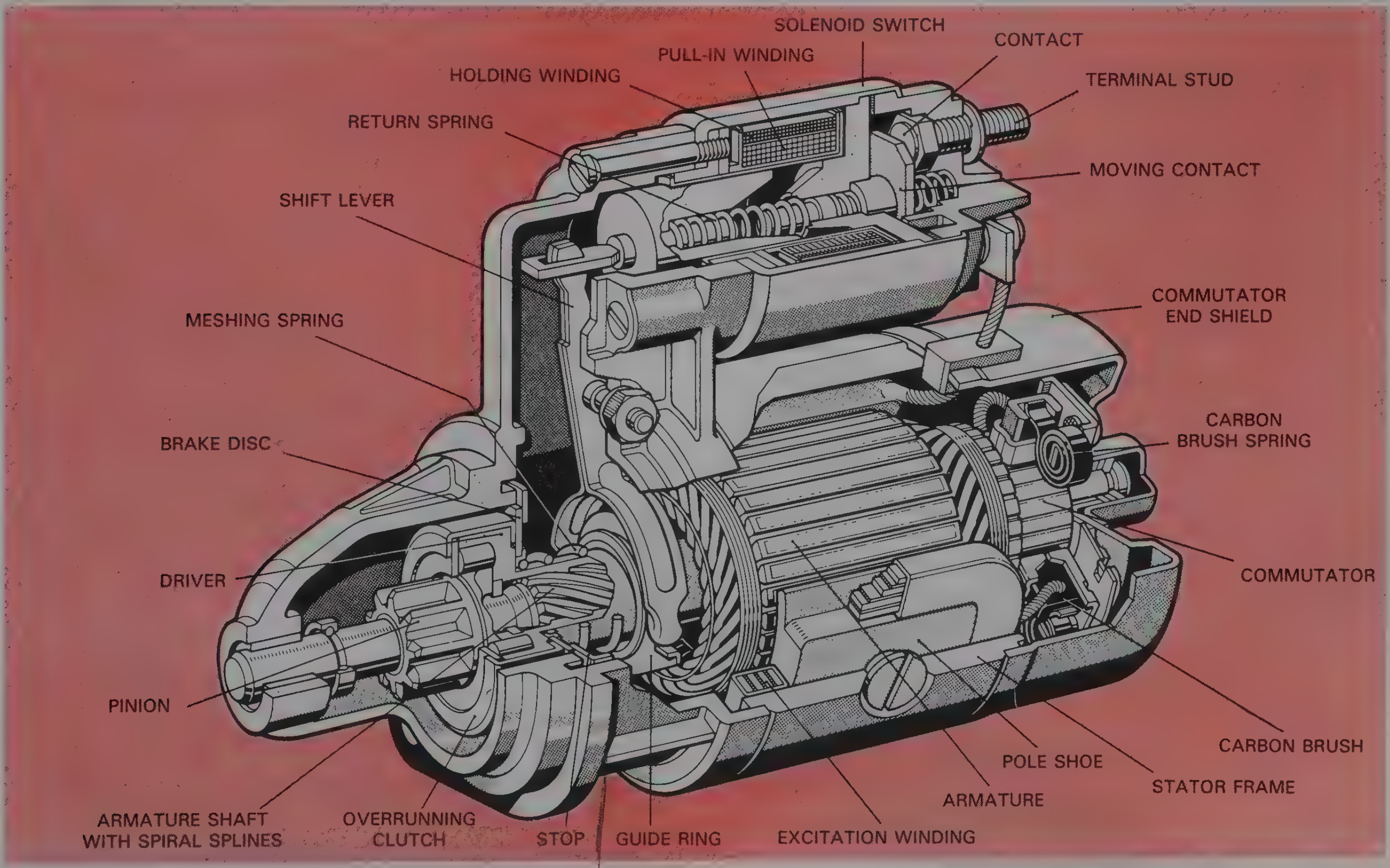

SOLENOID SWITCH
CONTACT
PULL-IN WINDING
HOLDING WINDING
TERMINAL STUD
RETURN SPRING
MOVING CONTACT
SHIFT LEVER
COMMUTATOR END SHIELD
MESHING SPRING
CARBON BRUSH SPRING
BRAKE DISC
COMMUTATOR
DRIVER
PINION
CARBON BRUSH
POLE SHOE
STATOR FRAME
ARMATURE
ARMATURE SHAFT WITH SPIRAL SPLINES
OVERRUNNING CLUTCH
STOP
GUIDE RING
EXCITATION WINDING

Fig. 23-107. Typical starter employing a solenoid-engaged, overrunning clutch drive. Solenoid also actuates starter motor. (Bosch)

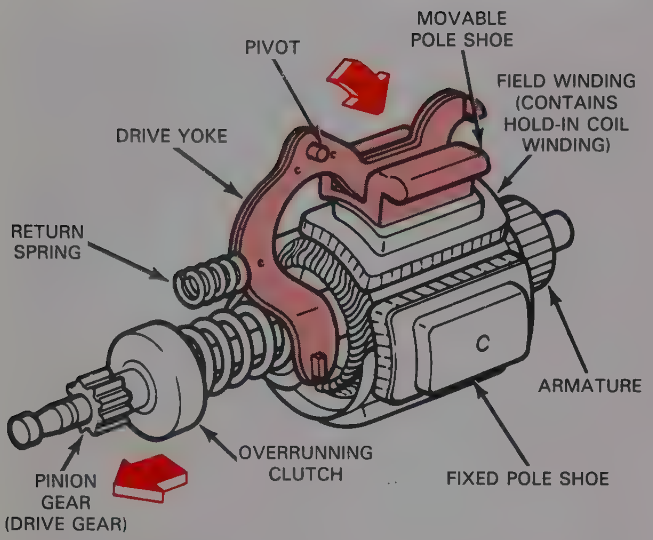

MOVABLE POLE SHOE
PIVOT
FIELD WINDING (CONTAINS HOLD-IN COIL WINDING)
DRIVE YOKE
RETURN SPRING
C
ARMATURE
OVERRUNNING CLUTCH
FIXED POLE SHOE
PINION GEAR (DRIVE GEAR)

Fig. 23-109. This starter uses a movable pole shoe device to actuate the starter drive gear. (AMC)

a movable pole shoe that is connected to the starter drive. When the starter is energized, magnetic action causes the pole shoe to slide sideways, thus engaging the starter drive pinion.

CLEANING STARTER

Clean all parts (except armature, field coil, commutator, and when used, overrunning clutch drive) in solvent. A rag, SLIGHTLY DAMPENED with clean solvent may be used to wipe off the armature, field coils, and outside of the overrunning clutch unit if they are oily. If no oil is present on these parts, use a soft brush, mild air pressure, or a clean, dry rag.

A Bendix drive may be cleaned in solvent. The overrunning clutch drive is factory packed with lubricant and must never be placed in solvent.

TESTING ARMATURE FOR SHORT CIRCUITS

Place the armature in a growler as in Fig. 23-110. Make sure the brush and copper dust are removed from between the commutator segments where the mica has been undercut.

Hold a thin steel strip (hacksaw blade is fine) loosely on the top of the armature (tip one edge up). Turn on the growler. Turn the armature until the entire armature core has passed beneath the strip. If a short circuit exists, the strip will vibrate when the shorted section passes under it. Do not operate the growler when the armature is not in place.

CHECKING ARMATURE FOR GROUNDS

Place one test prod (110 V test unit) on the armature core, Fig. 23-111. Touch each commutator segment, in turn, with the other prod. If the armature is grounded, the test lamp will light. Discard grounded or shorted armatures.

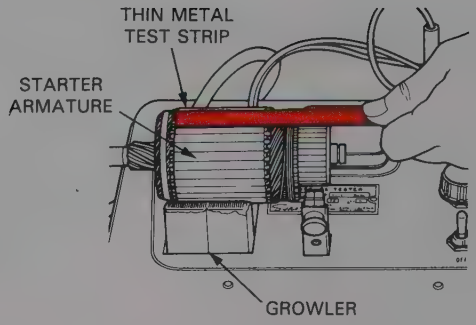

THIN METAL TEST STRIP
STARTER ARMATURE
GROWLER

Fig. 23-110. Using a growler to test starter armature for short circuits. (Chevrolet)

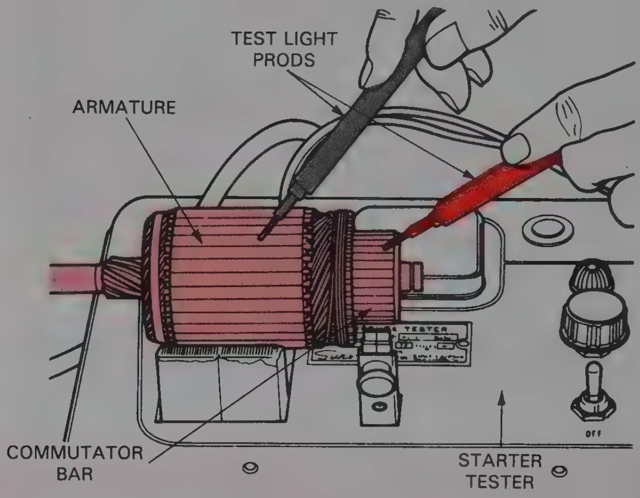

TEST LIGHT PRODS
ARMATURE
COMMUTATOR BAR
STARTER TESTER

Fig. 23-111. Checking starter armature for grounds. (Chrevrolet)

INSPECT COMMUTATOR BARS FOR OPENS

Prolonged cranking may overheat the starter and cause the solder on the conductor-to-commutator segment or bar connections to melt and be thrown off. Inspect the joints for missing solder. Also inspect the segments (especially trailing edges) for signs of burning that could indicate an open circuit. Refer to Fig. 23-112.

If the bars are not too badly damaged, resolder the connections and turn the commutator. Check the commutator for runout (should not exceed .003-.005 in. or 0.08-0.13 mm) and scoring, Fig. 23-113.

TURNING COMMUTATOR

Support the armature in a proper holding fixture or a lathe. Be certain that the armature shaft is centered properly.

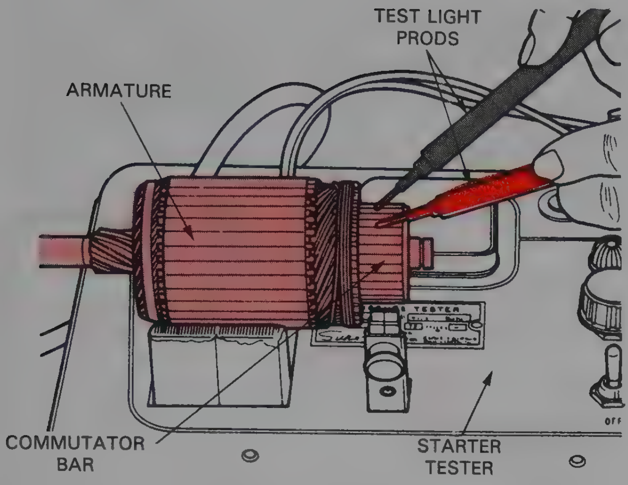

TEST LIGHT PRODS
ARMATURE
COMMUTATOR BAR
STARTER TESTER

Fig. 23-112. Testing armature coils for continuity (opens). (Chrevrolet)

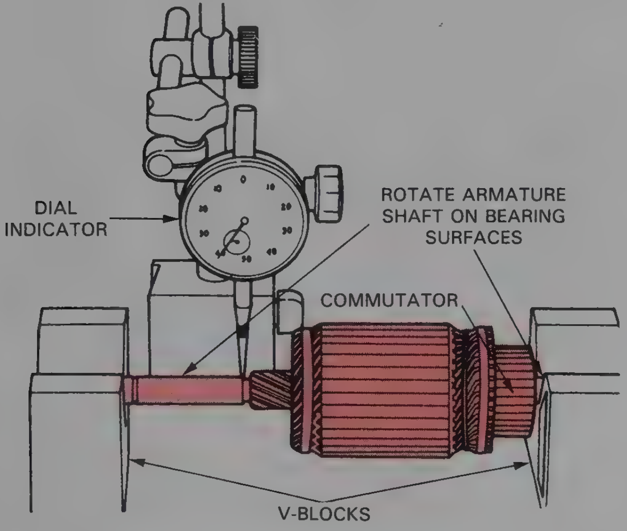

DIAL INDICATOR
ROTATE ARMATURE SHAFT ON BEARING SURFACES
COMMUTATOR
V-BLOCKS

Fig. 23-113. Checking starter shaft for runout. Dial indicator will also be moved to commutator surface to check it for runout. (Chevrolet)

Remove only enough copper from the commutator to clean up scoring, burning, or runout.

Although undercutting the mica (insulation between bars) is NOT GENERALLY REQUIRED on starter motors, some manufacturers do recommend that it be done. In such cases, follow all manufacturer's instructions. Sand lightly with No. 400 abrasive sandpaper when finished. Do not use emery cloth. See Fig. 23-114.

TEST FIELD COILS FOR OPENS

Use a 110 volt test light. Be careful to avoid shocks. Place one test prod on the coil terminal stud or on the connector from the solenoid, Fig. 3-115. Place the other prod on the insulated brush lead. This, in effect, places a prod on each end of the field coils. Test lamp should light. No light indicates an open circuit.

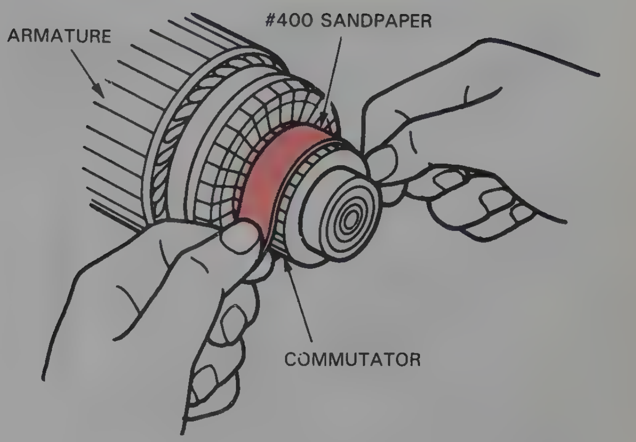

ARMATURE
#400 SANDPAPER
COMMUTATOR

Fig. 23-114. Sand commutator with No. 400 paper and clean thoroughly when finished. (Chevrolet)

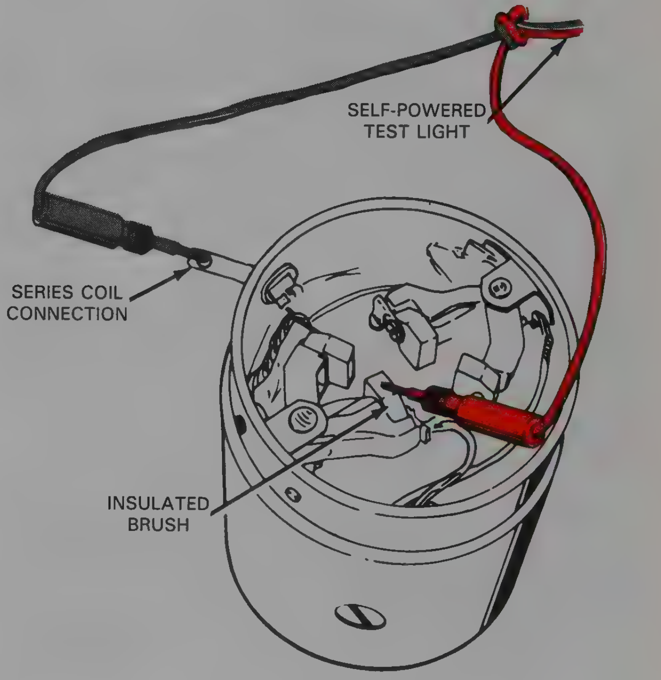

SELF-POWERED TEST LIGHT
SERIES COIL CONNECTION
INSULATED BRUSH

Fig. 23-115. Testing starter field coil for opens. (Buick)

TEST FIELD COILS FOR GROUNDS

Use a 110 volt test light. Place one prod on the field coil connector and the other on the frame. Lamp should not light. A lighted lamp indicates a ground. Be certain no part of the field circuit, brushes, or connectors are touching the frame. If the starter uses a shunt coil, disconnect the shunt before making the test. See Fig. 23-116.

BRUSHES

Recommended practice calls for replacing brushes when worn to within one-half of their original length—or if oil soaked. If the starter is dismantled for another

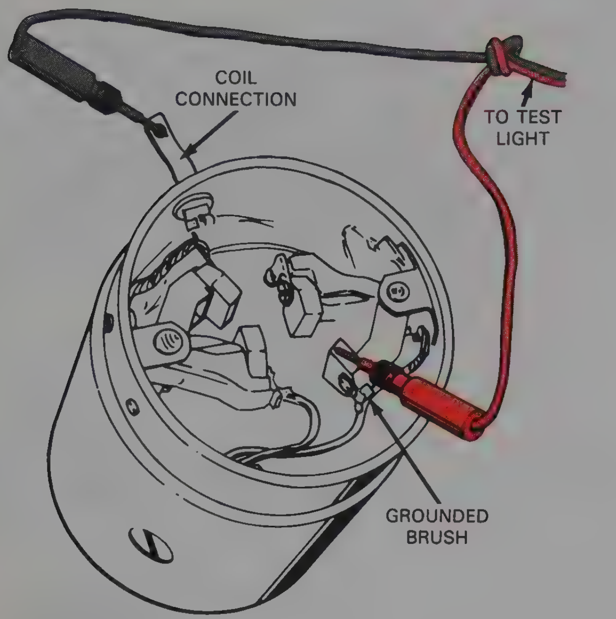

COIL CONNECTION
TO TEST LIGHT
GROUNDED BRUSH

Fig. 23-116. Testing starter field coils for grounds. (Buick)

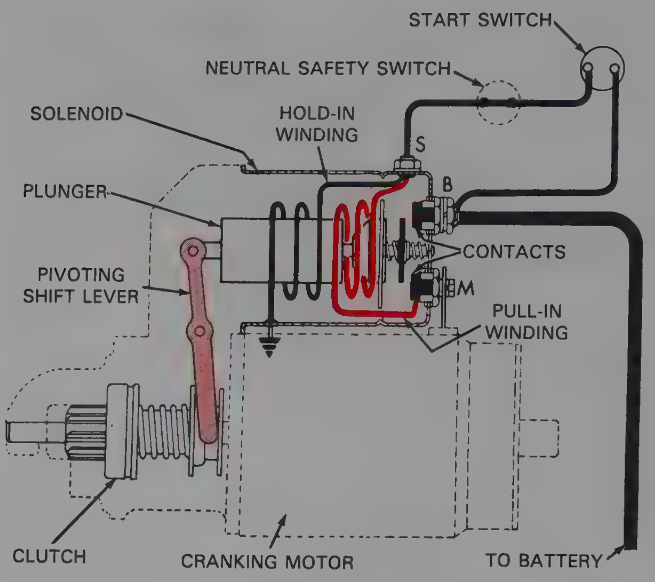

START SWITCH
NEUTRAL SAFETY SWITCH
SOLENOID
HOLD-IN WINDING
S
B
PLUNGER
CONTACTS
PIVOTING SHIFT LEVER
M
PULL-IN WINDING
CLUTCH
CRANKING MOTOR
TO BATTERY

Fig. 23-118. Typical starter solenoid. Note winding arrangement. (GM)

reason, REPLACE THE BRUSHES REGARDLESS OF THEIR LENGTH. When soldering is required, make certain solder joint is sound. Use high temperature solder.

Check insulated brush holders for grounds, Fig. 23-117. Make sure the brushes slide freely. If fastened to movable arms, the arms should be free and in alignment.

TESTING STARTER SOLENOID

In addition to a clean, functional set of contacts, proper solenoid operation requires sound pull-in and hold-in windings. Study the typical starter solenoid winding circuit in Fig. 23-118.

One commonly used solenoid winding test setup is shown in Fig. 23-119.

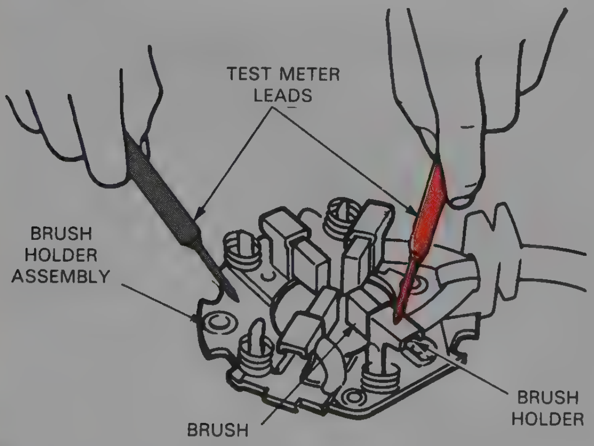

TEST METER LEADS
BRUSH HOLDER ASSEMBLY
BRUSH
BRUSH HOLDER

Fig. 23-117. Testing the starter insulated brush holders for ground with a test meter. (Geo)

With the solenoid in place on the starter, remove all leads. Depending on which winding is to be tested, make the hookups as indicated in Fig. 23-119. With switch ON, adjust carbon pile to produce manufacturer's specified voltage. Check ammeter reading.

If the ammeter reading EXCEEDS specified levels, it indicates a grounded or shorted circuit. A LOW reading is caused by excessive resistance. If no ammeter reading is apparent, the circuit is open.

WARNING! When testing PULL-IN winding, do not leave the circuit energized for longer than 15 seconds. This will prevent overheating. Keep in mind that as the circuit heats up, resistance increases and current draw decreases.

As with all tests, use a test procedure and specifications for the exact unit.

OTHER STARTER CHECKS

Inspect the bushings and replace if excessive wear is present. Check brush spring tension, Fig. 23-120. Inspect both pinion and flywheel gear teeth for any evidence of chipping, milling, cracking, or improper engagement pattern. The overrunning drive must turn fairly free in the coast direction and lock tight in the drive direction. Thrust washers and spacers must be in good condition. The Bendix drive, where used, must be clean and in good condition.

Check all soldered connections. Check pinion housing for signs of cracking.

STARTER ASSEMBLY

Assemble the starter in the reverse order of disassembly. If necessary, lubricate the two bushings with several drops of recommended lubricant. Wipe a thin coat of light lubricant on the armature shaft splines. NEVER lubricate unless specified by the manufacturer.

Where soldering is required, use ROSIN CORE SOLDER ONLY.

Some starters use a sealer in some locations to prevent the entry of dust and water. When assembling the parts, apply a nonhardening type sealer. Where grommets are used, they must be in good condition and properly inserted.

Torque the through-bolts to specifications. Check overrunning clutch pinion clearance by either forcing (where possible) the solenoid arm to the fully applied position or by energizing the starter solenoid. When energizing the solenoid, do not apply enough voltage to turn the motor – 6 volts for a 12-volt starter is about right. The solenoid motor terminal can also be connected to ground to help prevent starter rotation.

When the solenoid has moved the pinion to the fully engaged position, push the pinion back to remove all slack. Measure the clearance between pinion and pinion stop. Look at Fig. 23-121.

Pinion clearance is adjustable on some starters. On many units, however, clearance cannot be adjusted. When it is wrong, it must be corrected by installing new parts.

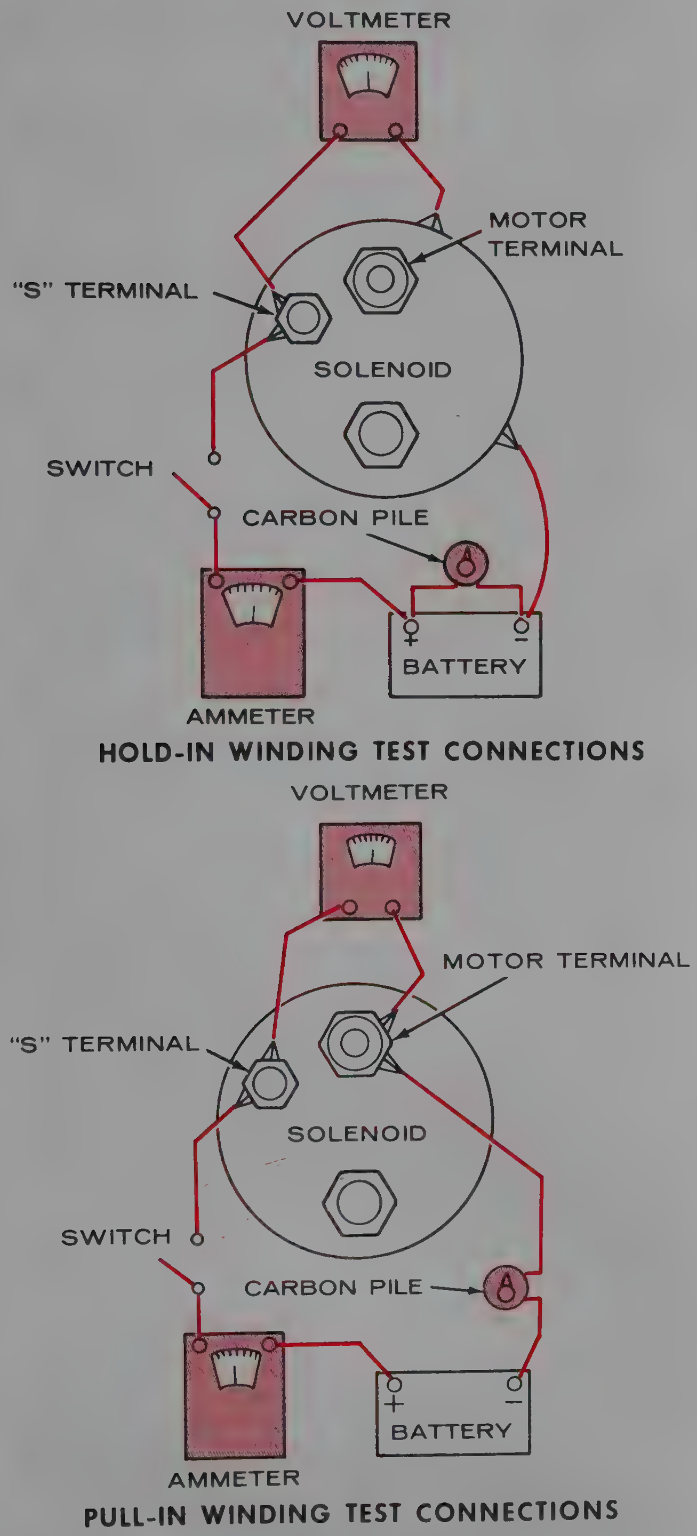

VOLTMETER
MOTOR TERMINAL
"S" TERMINAL
SOLENOID
SWITCH
CARBON PILE
BATTERY
AMMETER
HOLD-IN WINDING TEST CONNECTIONS
VOLTMETER
MOTOR TERMINAL
"S" TERMINAL
SOLENOID
SWITCH
CARBON PILE
+
−
BATTERY
AMMETER
PULL-IN WINDING TEST CONNECTIONS

Fig. 23-119. Testing starter solenoid hold-in and pull-in winding circuits. (GM)

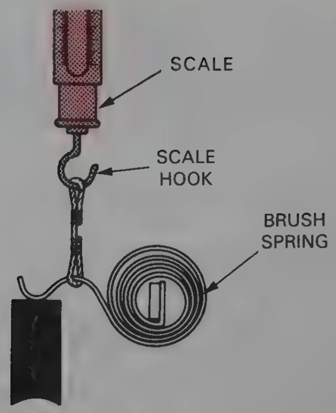

SCALE
SCALE HOOK
BRUSH SPRING

Fig. 23-120. Testing starter brush spring tension with a spring scale. (Geo)

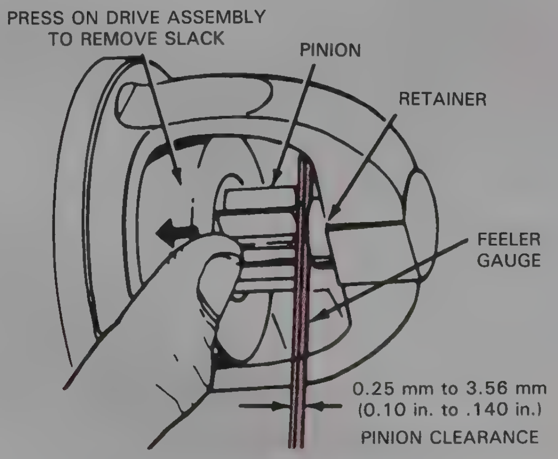

PRESS ON DRIVE ASSEMBLY TO REMOVE SLACK
PINION
RETAINER
FEELER GAUGE
0.25 mm to 3.56 mm
(0.10 in. to .140 in.)
PINION CLEARANCE

Fig. 23-121. Pinion gear clearance is checked with a feeler gauge. (Pontiac)

TEST STARTER

When assembly is complete, give the starter a NO-LOAD and STALL TORQUE test before attaching to the engine.

INSTALLING THE STARTER

Disconnect battery ground strap. Clean mounting flange or pad until spotlessly clean. This is necessary for proper electrical ground and for accurate mechanical alignment. Install starter and torque fasteners.

Some starter setups permit measuring flywheel-to-pinion clearance. Fig. 23-122 illustrates the use of a wire gauge to determine such clearance on one setup.

If the pinion-to-flywheel clearance is incorrect, it is often possible to bring it within the specified range by using mounting shims to tip the starter slightly. This must be done carefully. Make a final clearance check following tightening.

Connect wiring. Connect battery ground strap. Try starter.

Remember that all splash and/or heat shields, sealing gaskets, and brackets must be in good condition and in place.

SUMMARY—IGNITION SYSTEM SERVICE

The first step in ignition system problem diagnosis is to visually inspect all system components.

Primary wiring must be in good condition. The battery should be fully charged and properly connected. Check the coil and distributor cap for flashover, burning, or corrosion. Coil polarity must be correct. Secondary wiring must be in good condition. All terminals should be properly connected. Wire ends should have good boots and should be fully inserted into the correct towers.

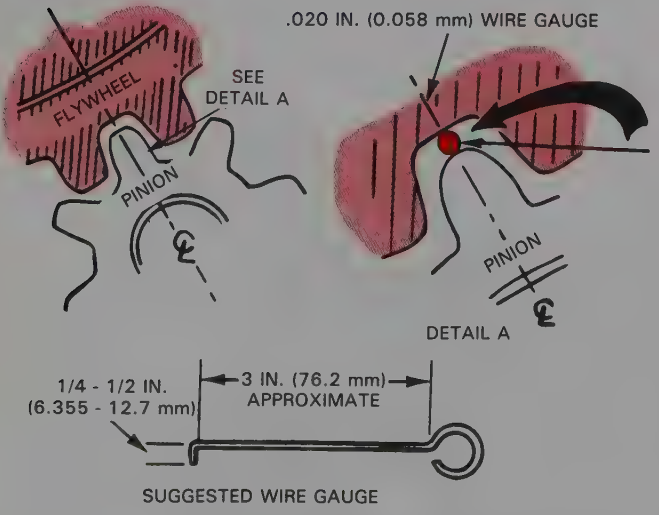

.020 IN. (0.058 mm) WIRE GAUGE
FLYWHEEL
SEE DETAIL A
PINION
℄
PINION
℄
DETAIL A
1/4 - 1/2 IN. (6.355 - 12.7 mm)
3 IN. (76.2 mm) APPROXIMATE
SUGGESTED WIRE GAUGE

Fig. 23-122. Checking starter drive pinion-to-flywheel gear tooth mesh depth clearance. (Pontiac)

If the engine will crank but will not start, a spark test can be used to isolate the problem. Problems in the primary circuit may be caused by the ignition switch, resistor, or coil. The distributor, rotor, and spark plug wires can cause trouble in the secondary circuit.

Handle plug wires carefully. Pull on the boot or terminal rubber jacket. Avoid sharp bends. Plug wires should have specified resistance. Arrange them to prevent cross firing.

Firing order always starts with the number one cylinder and proceeds as specified by the manufacturer.

Change secondary wires one at a time or mark all wires before removal. Always use new boots.

Most electronic distributor pickup units can be tested with an ohmmeter. If a component's resistance is not within specifications, it must be replaced.

Breaker points must be properly cleaned and gapped. Distributor cam should be lubricated if recommended by the manufacturer. A dwell meter should be used to set the cam angle (dwell). Dwell adjustments are not necessary in electronic ignition systems.

Electronic ignition control modules are usually tested with a voltmeter or an ohmmeter. Some units require the use of special testing equipment. Some technicians heat the ignition control module to help locate intermittent problems. Always follow manufacturer's recommendations.

Distributor vacuum and centrifugal advance units should be tested for correct operation. Many automobiles use a computer to control ignition timing. Most computerized systems have self-diagnostic capabilities.

A distributor tester does an accurate job of checking shaft, cam, dwell, point bounce, and advance units. Worn distributors can be overhauled.

When installing a distributor, make certain that the timing is correct, the oil pump shaft is engaged, and the distributor is locked into position. A stroboscopic timing light is used to set ignition timing.

Clean around spark plugs before removing. Clean and gap plugs every 5000 miles (8 000 km). Examine for abnormal wear and deposits. Replace when necessary.

An oscilloscope can be used for quick and accurate ignition system diagnosis. Use as recommended by the manufacturer.

SUMMARY—BATTERY SERVICE

Batteries can explode. Be careful! Wear gloves and goggles when handling electrolyte.

Keep battery hold-down snug, cable connections clean and tight, and electrolyte up to the proper level.

Use distilled water, unless tap water has been tested and found OK.

Where possible, specific gravity should be checked with a hydrometer. Correct reading to temperature.

Where battery is of sealed construction, state of charge can be determined by either studying the built-in hydrometer "eye" or by using suitable test instruments.

Charge batteries that are less than 75 percent charged.

Battery open circuit voltage can be determined with a low reading voltmeter. Cell voltage should be 2.06 volts or more. Cell variation should not exceed about 0.5 volts.

Batteries may be recharged either by slow charging or by fast charging. Slow charging is preferable when time permits.

Wet batteries may be kept charged in storage by trickle charging. Be careful to avoid overcharging. Store in a cool area.

Store dry-charged batteries in a cool, DRY spot.

When activating a dry-charged battery, fill with specified electrolyte. Fast charge until the specific gravity is at least 1.240 and the electrolyte temperature is 80°F (27°C) or above.

A replacement battery should equal or exceed the original in ampere-hour capacity. Never use a 12-volt battery in a 6-volt system or vise versa.

Three popular battery capacity ratings are CRANKING PERFORMANCE, 20-HOUR RATING, and RESERVE CAPACITY.

When installing the battery, be sure to ground the correct terminal. Current U.S. cars ground the NEGATIVE. A negative post is smaller in diameter and may have a NEG, N, or — stamped on the top.

A voltmeter may be used to check for battery drain.

When using battery jumper cables to connect a booster battery, connect booster positive to car battery positive and negative to car frame or engine.

SUMMARY—ALTERNATOR-REGULATOR SERVICE

Charging system problems can involve the alternator, regulator, wiring, battery, or any combination of the four.

When repairing or replacing one unit, check the others also.

Always disconnect the battery ground strap before making any test connections or before removing or replacing any part of the alternator system.

Check alternator system for excessive resistance by measuring field circuit resistance, the alternator-to-battery positive terminal resistance, and the alternator-to-battery ground resistance.

Check alternator output against specifications.

Test alternator diodes with a special tester, an ohmmeter or with a test light. Protect diodes from excessive heat and from mechanical shock. Use a press to remove and replace the diodes.

Clean all alternator parts, EXCEPT ROTOR, STATOR, AND BRUSH ASSEMBLIES, in solvent. DO NOT WASH SEALED BEARINGS.

Replace alternator brushes during overhaul.

Test rotor for opens, shorts, and grounds. Check stator windings for opens, shorts, and grounds.

Inspect the slip rings for signs of scoring and burning. If needed, turn and polish with No. 400 sandpaper. Test alternator capacitor.

When working on alternator regulators, observe all the normal alternator system cautions.

Many electronic regulators are nonadjustable and must be replaced if malfunctioning.

SUMMARY—STARTER SERVICE

Before condemning the starter, check the battery condition. Check the battery cables, connections, and entire starter system wiring for high resistance. Clean and tighten connections and replace wiring where indicated.

When conducting starter tests, do not operate the starter for any longer than 20-30 seconds. Allow a two minute cooling off period before resuming cranking.

Check solenoids, switches, and relays for excessive resistance, shorting, and mechanical faults.

The starter NO-LOAD test, the LOAD test, and the STALL TORQUE test may be used as required to check starter performance and current draw.

Clean all parts of the starter, except the armature, field coils, commutator, bushes, and where used, the overrunning clutch, in solvent.

Test armature for short circuits and grounds. Check commutator bars for indication of an armature open.

Check commutator for runnout, burning, and scoring. Turn and polish with No. 400 sandpaper when required. Do not use emery cloth!

When turning the commutator, remove only enough copper to clean up. Undercut the mica if recommended by manufacturer.

Test field coils for opens and grounds. Check brush holders for grounds. Inspect soldered connections.

When using 110 volt test equipment, be careful to avoid shocks.

Replace starter brushes during overhaul.

Check starter bushings and armature shaft bearing area. Inspect pinion gear and Bendix or overrunning clutch drive unit. Check pinion housing for cracks.

Lubricate starter bushings with a few drops of 20W oil during starter assembly. Coat armature shaft splines with a light coat of Lubriplate. If a Bendix drive is used, oil lightly.

Check pinion clearance. Install all grommets snugly. Use nonhardening sealer where required. Torque through-bolts. Clean starter mounting pad and torque mounting fasteners. Replace heat shields and brace brackets. Test starter function.

KNOW THESE TERMS

Primary circuit, Secondary circuit, Resistance, Flashover, Coil polarity, Cross firing, Firing order, Breaker points, Condenser, Dwell, Centrifugal advance, Vacuum advance, Ignition timing, Spark plug, Oscilloscope, Electronic ignition, Electrolyte, Vent plug, State of charge, Specific gravity, Hydrometer, Battery capacity, Fast charging, Slow charging, Dry charged battery, Polarity, Voltage regulator, Diode, Collector ring, Armature, Transistorized, Stall torque, Current draw, Open windings, Growler, Commutator segment or bar, Bendix drive, Jumper cables, Movable pole shoe, Overrunning clutch, Alternator, Dielectric.

QUIZ - Chapter 23

IGNITION SYSTEM QUESTIONS:

1. Excessive circuit resistance lowers __________.
2. A spark test can be used to help pinpoint ignition system problems. True or False?
3. What is meant by coil "available" voltage?
4. Secondary wire towers should be checked for __________, __________, and __________.
5. The spark plug center electrode must have a __________ polarity.
6. If checking coil polarity with a voltmeter, if the polarity is correct, the needle will flick __________ scale.
7. Reversed coil polarity can be easily detected on the oscilloscope because the waveform will appear:
   a. Normal, but backward.
   b. Right side up, but with broken lines.
   c. Normal, but upside down.
8. It is possible for plug wires to have excessive resistance. True or False?
9. When wires serving two adjacent cylinders on the same bank, that fire consecutively, run together for a certain distance, __________ is likely to occur.
10. Firing order means:
    a. The order in which cylinders fire.
    b. That a piston is at top dead center on the firing stroke.
    c. The direction the distributor turns.
11. A normal color for ignition points would be:
    a. Deep blue.
    b. Reddish brown.
    c. Dull gray.
12. Point gap affects dwell. True or False?
13. Initial point gap can be set with a wire feeler gauge. True or False?
14. The condenser, when faulty, can cause rapid burning of the points. True or False?
15. Increasing the point gap __________ the dwell.
16. Computerized ignition systems eliminate the need for __________ and __________ advance systems.
17. The distributor centrifugal advance unit is adjusted by altering the return spring pressure. True or False?
18. All vacuum advance units are adjustable. True or False?
19. When timing the engine with a stroboscopic light, it is often necessary to disconnect the __________ __________ to the distributor.
20. Set the timing before setting the dwell. True or False?
21. Computerized ignition systems are equipped with __________ that monitor various engine operating conditions.
22. Many electronic ignition systems have self-diagnostic capabiities. True or False?
23. Spark plugs should be cleaned and gapped every 5000 miles (8 000 km). True or False?
24. Plug fuel fouling is indicated by a __________, __________, __________ deposit. (Color.)
25. Plug oil fouling is indicated by a __________, __________, deposit. (Color.)
26. Plug overheating is indicated by __________, __________, __________ insulator.
27. When gapping plugs, bend the __________ electrode only.
28. To assure correct spark plug tightening, use a __________ __________.
29. When selecting a new set of plugs, the __________, __________, and __________ __________ should be considered.

BATTERY SERVICE QUESTIONS:

30. Battery electrolyte is made up of __________ and __________ __________.
31. When mixing or adding electrolyte to batteries, wear __________ and __________ __________ to protect against burns.
32. Wash the skin with __________ to remove battery acid.
33. Battery corrosion may be readily removed with a solution of __________ __________ and __________.
34. The electrolyte level should be about 3/8 in. (9.5 mm) below the top of the plates. True or False?
35. When the electrolyte level is low, bring it up by adding __________.
36. Battery specific gravity indicates ampere-hour capacity. True or False?
37. Use only __________ water or approved __________ water for battery service.
38. The following instrument is used to test electrolyte specific gravity:
    a. Voltmeter.
    b. Hydrometer.
    c. Ammeter.
    d. Specificometer.

39. Average full charge specific gravity would be between:
    a. 1.260 - 1.280.
    b. 1.110 - 1.130.
    c. 1.400 - 1.450.
    d. 1.200 - 1.220.
40. Specific gravity readings must be ____________ corrected.
41. Battery capacity or efficiency is improved by cold weather. True or False?
42. A battery should be recharged when the specific gravity reading indicates the state of charge is reduced to:
    a. 50 percent charged.
    b. 25 percent charged.
    c. 75 percent charged.
    d. Any of the above.
43. Open-circuit voltage should be checked immediately after charging a battery. True or False?
44. Open circuit voltage should be approximately ____________ volts.
45. The ____________ test is a more accurate indication of battery condition than either the open voltage or specific gravity test.
46. When a battery fails the ____________ test, it should be given a three-minute charge test.
47. When time is available, slow charging is preferable to fast charging. True or False?
48. Fast charging applies a charge rate of around ____________ amperes for 12-volt batteries.
49. When fast charging a group of batteries, connect the batteries in ____________.
50. When slow charging a group of batteries, connect the batteries in ____________.
51. When installing a battery, always connect the ____________ strap last.
52. Current American made cars use a ____________ ground.
53. The battery positive post may be identified by:
    a. Being wider than the negative post.
    b. Being painted red.
    c. By a + or POS stamped on the post.
    d. By using any three of the above.
54. When connecting a booster battery to a dead battery in a car, hook the booster POS to the car battery ____________ and booster NEG to the ____________.
55. A 12-volt battery will work fine in a 6-volt system. True or False?

ALTERNATOR-REGULATOR SERVICE QUESTIONS:

56. Before conducting charging system tests, it is very important that a __fully__ __charged__ battery be installed.
57. When a unit is found to be defective and it is replaced, it is safe to assume the problem is solved. True or [✓ False?]
58. The charging system should be checked for excessive __resistance__.
59. When cleaning the alternator, what parts must NOT be cleaned in solvent. Name four. brushes Rotor [illegible]
60. When overhauling an alternator, always install __New__ brushes.
61. List 10 important precautions regarding service work on alternator charging systems.
62. Under certain conditions, alternators are capable of producing voltages high enough to be dangerous to anyone touching the output terminal. [✓ True] or False?
63. Always __[illegible]__ the battery __lead__ __Ground__ before connecting or disconnecting any unit in the alternator system.
64. The alternator system should be checked for excessive resistance. [✓ True] or False?
65. Diode damage causes a high percentage of alternator problems. True or False?
66. Diodes may be tested with:
    a. An ohmmeter.
    b. Special diode tester.
    c. A test lamp.
    [✓ d.] With all three of the above. Heat
67. Diodes are easily damaged by __Battery o__ and __booster__. Charged
68. Alternator slip rings should be polished with:
    [✓ a.] No. 400 sandpaper.
    b. 00 emery cloth.
    c. Crocus cloth.
    d. Any of the above three.
69. Alternator rotor and stator windings should be checked for opens, shorts, and grounds. [✓ True] or False?
70. Always polarize the alternator after installation. True or False?
71. Electronic regulators have:
    a. One set of points.
    b. Two sets of points.
    [✓ c.] No points. Rosin core
    d. One point and one diode.
72. Use __Rosin__ __Core__ solder for all electrical work.
73. All regulators are adjustable. True or [✓ False?]

STARTER SERVICE QUESTIONS:

74. Check the starter circuit for __voltage__ __drop__ and if it is discovered, clean and tighten connections as required.
75. Never operate starter continuously for period exceeding following:
    a. 1 minute.
    b. 20-30 minutes.
    [✓ c.] 20-30 seconds.
    d. 5 seconds.

76. List three starter motor tests.

77. Efficient starter operation is most dependent upon:
    - [✓ a.] A fully charged battery.
    - b. Proper engine oil.
    - c. A well oiled starter drive.
    - d. A dust free armature.

78. Never clean starter Armature field coil, over running, or commotator with solvent.

79. Check armature for open, short, ground, and ~~ground~~. High resistance

80. When a starter commutator is turned, the mica MUST ALWAYS be undercut. True or [✓ False]?

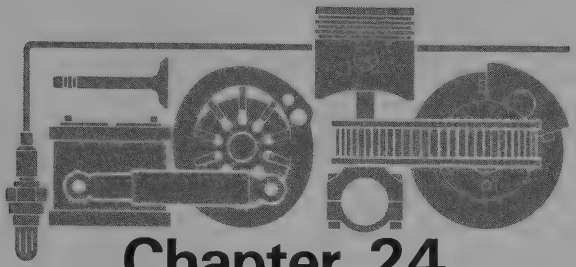
81. Test starter field coils for Short and open.

82. Starter pinion gear-to-pinion stop clearance is automatic and cannot be adjusted. True or False?

83. Wash the overrunning clutch type starter drive in solvent. True or [✓ False]?

84. The Bendix drive and armature shaft should be left clean and dry for proper operation. True or [✓ False]?

85. Starter brushes are satisfactory unless worn to 1/4 of their original length. True or [✓ False]?



Chapter 24

COMPUTER SYSTEM SERVICE

After studying this chapter, you will be able to:

- ☐ Explain the stages of computer control system operation.
- ☐ Define control loops.
- ☐ Explain the function and operation of various sensors and actuators.
- ☐ Troubleshoot and service sensors, actuators, and electronic control units.
- ☐ Work safely on vehicles equipped with air bag systems.
- ☐ Troubleshoot and service air bag and anti-lock brake systems.
- ☐ Explain the operation of traction control systems and computerized ride control systems.

CAUTION: This chapter is designed to be used as a supplement to the manufacturer's service manual when troubleshooting and servicing automotive computer systems. It is not intended to replace the service manual. Computer control systems vary among manufacturers. Always consult the appropriate manual before attempting to service a computer system. Incorrect testing procedures can destroy delicate computer system components.

INTRODUCTION

The computer control systems found in today's automobiles consist of complicated networks of electronic components. The untrained technician cannot service vehicles equipped with these systems based on mechanical aptitude alone. The most important tool for troubleshooting and servicing computer control systems is a thorough understanding of how they operate.

This chapter will provide the general theory necessary to tackle computer control system problems. It covers the operation, diagnosis, and service of the most common computer control system components. Some of the typical computer control system components used in today's automobile are illustrated in Fig. 24-1.

WHY COMPUTERS?

The use of computers in the automotive industry was prompted by governmental regulations requiring manufacturers to build fuel efficient vehicles that produced fewer exhaust emissions. Computerized engine control systems offered accurate and instantaneous control over the fuel, ignition, and emission systems. These control systems provided better gas mileage, lower exhaust emissions, and smoother operation than their mechanical predecessors. Most components in a computerized system are not subject to physical wear and, therefore, do not require periodic replacement or adjustment.

In addition to precisely controlling engine operating conditions, computers are used to govern various systems in today's automobile, including the brake system, the occupant restraint (air bag) system, and the suspension system.

COMPUTER CONTROL SYSTEM COMPONENTS

In order to control operating conditions within an automobile, the computer control system must be able to monitor and alter these conditions, Fig. 24-2. To accomplish this, most systems use the following components:

1. Sensors (convert physical conditions to electrical input signals).
2. Electronic control unit (computer that processes

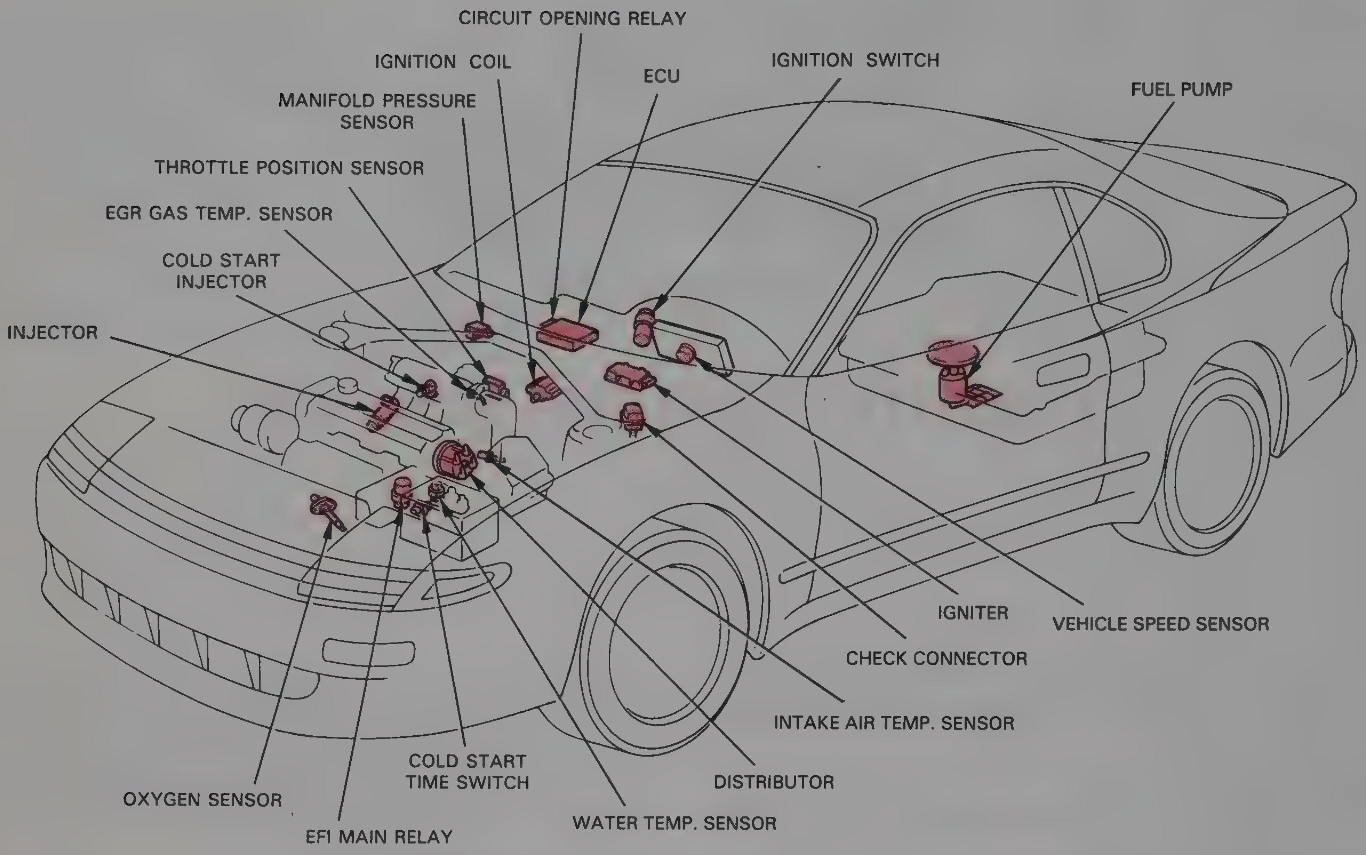

CIRCUIT OPENING RELAY
IGNITION COIL
ECU
IGNITION SWITCH
FUEL PUMP
MANIFOLD PRESSURE SENSOR
THROTTLE POSITION SENSOR
EGR GAS TEMP. SENSOR
COLD START INJECTOR
INJECTOR
IGNITER
VEHICLE SPEED SENSOR
CHECK CONNECTOR
INTAKE AIR TEMP. SENSOR
DISTRIBUTOR
COLD START TIME SWITCH
WATER TEMP. SENSOR
OXYGEN SENSOR
EFI MAIN RELAY

Fig. 24-1. Modern computer control systems use several common components. Note location of various parts. (Toyota)

*** OPERATING PARAMETERS SENSED**

- A/C "On" or "Off"
- Engine Coolant Temperature
- Engine Crank Signal
- Exhaust Oxygen
- Ignition Reference
  - Crankshaft Position
  - Engine Speed (RPM)
- Manifold Absolute Pressure
- Park Neutral Switch (P/N) Position (A/T only)
- System Voltage
- Throttle Position
- Transmission Gear Position (A/T only)
- Vehicle Speed
- Manifold Air Temperature
- EGR Vacuum (California only)

→ **ELECTRONIC CONTROL UNIT (ECU)** →

*** SYSTEMS CONTROLLED**

- Air Management
- Canister Purge
- Exhaust Gas Recirculation (EGR)
- Electronic Spark Timing (EST)
- Fuel Control
- Idle Air Control (IAC)
- Electric Fuel Pump
- Air Conditioning
- Diagnostics
  - "Check Engine" Light

***Not all items are used on all engines.**

Fig. 24-2. Computer systems monitor and control many systems throughout the automobile. The electronic control unit analyzes signals that represent operating parameters and adjusts operating systems based on these signals. (Geo)

input signals and supplies output data).
3. Actuators (convert output signals into physical actions).

COMPUTER CONTROL SYSTEM STAGES

Computer control systems can be broken down into three stages of operation: the input stage, the processing stage, and the output stage. See Fig. 24-3. These stages are repeated thousands of times each second during computer control system operation.

INPUT STAGE

The input stage is the first step in the computer control process. During this stage, sensors monitor various operating conditions and send electrical signals, which represent these conditions, to the electronic control unit (ECU).

PROCESSING STAGE

During the processing stage, the electronic control unit analyzes the input signals from the sensors. It uses this input information to decide if an adjustment needs to be made in the monitored operating system. If an adjustment is required, the decision of how it will be made occurs in the processing stage.

OUTPUT STAGE

During the output stage, the computer carries out the decisions made in the processing stage. Electrical signals, representing these decisions, are sent to output devices called actuators. Actuators make physical adjustments to change engine operating conditions.

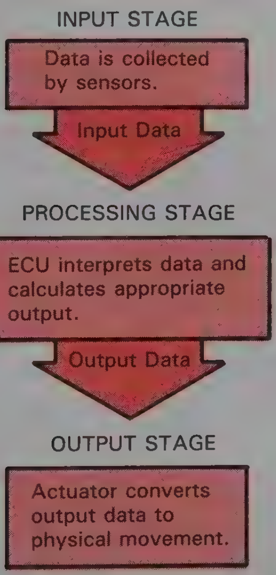

INPUT STAGE
Data is collected by sensors.
Input Data
PROCESSING STAGE
ECU interprets data and calculates appropriate output.
Output Data
OUTPUT STAGE
Actuator converts output data to physical movement.

Fig. 24-3. Computer control system operation occurs in specific stages. These stages are repeated constantly during system operation.

COMPUTERIZED ENGINE CONTROL COMPONENTS

Sensors, actuators, and control units are used to govern many systems in a vehicle. For clarity, however, the following sections on the operation, troubleshooting, and service of computer system components will emphasize the actuators, sensors, and control units that affect engine operating conditions, Fig. 24-4. Air bag systems, anti-lock brake systems, and computerized suspension systems will be covered in detail later in this chapter.

SENSORS

Sensors are used to monitor various operating conditions throughout the automobile. Many technicians refer to sensors as transducers. A transducer can be defined as a device that converts an input to an output of a different form. Sensors convert physical conditions into electrical signals. The electronic control unit uses sensor signals to analyze operating conditions.

SIGNAL-PRODUCING SENSORS

In response to specific operating conditions, some sensors generate a voltage signal, Fig. 24-5. This signal is sent to the electronic control unit for processing. Typical signal-producing sensors include:
1. Oxygen sensors.
2. Engine speed sensors.
3. Detonation sensors.

OXYGEN SENSORS

The oxygen (O_2) sensor is one of the most important sensors on today's automobile, Fig. 24-6. It is used to monitor the amount of oxygen in the engine's exhaust gas and is usually located in the exhaust manifold.

Most oxygen sensors operate like a small battery. Differences in oxygen content between the sensor's inner and outer surfaces cause it to generate a small voltage signal. As the oxygen content of the exhaust gas changes, the sensor's voltage signal also changes. The electronic control unit uses information from the oxygen sensor to monitor the engine's air-fuel ratio. A faulty oxygen sensor can cause an excessively rich or lean fuel mixture.

LOOP OPERATION

When the computer control system is receiving inputs from the sensors, processing these inputs, and

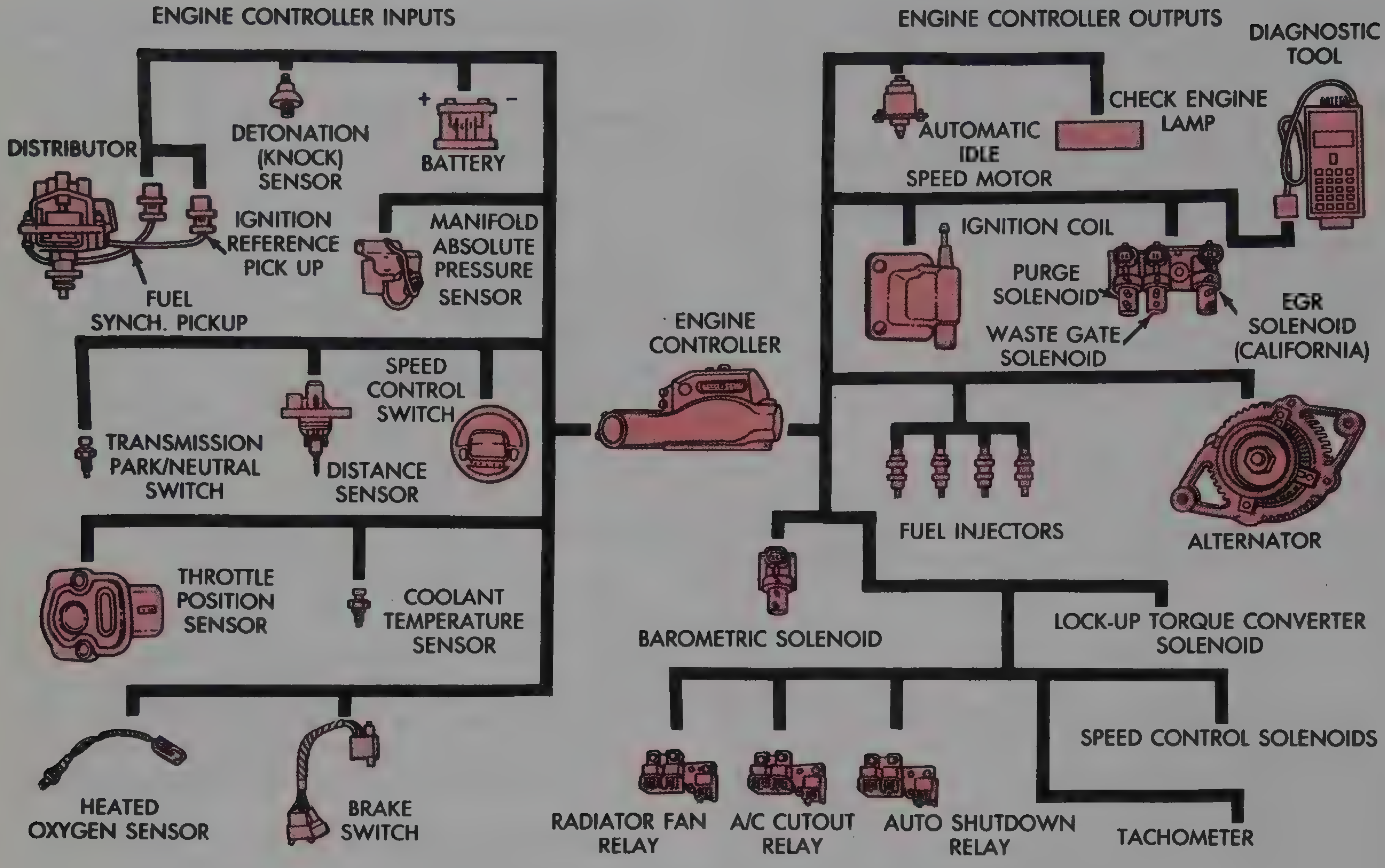

ENGINE CONTROLLER INPUTS
DISTRIBUTOR
DETONATION (KNOCK) SENSOR
+
-
BATTERY
IGNITION REFERENCE PICK UP
MANIFOLD ABSOLUTE PRESSURE SENSOR
FUEL SYNCH. PICKUP
SPEED CONTROL SWITCH
TRANSMISSION PARK/NEUTRAL SWITCH
DISTANCE SENSOR
THROTTLE POSITION SENSOR
COOLANT TEMPERATURE SENSOR
HEATED OXYGEN SENSOR
BRAKE SWITCH
ENGINE CONTROLLER
ENGINE CONTROLLER OUTPUTS
DIAGNOSTIC TOOL
AUTOMATIC IDLE SPEED MOTOR
CHECK ENGINE LAMP
IGNITION COIL
PURGE SOLENOID
WASTE GATE SOLENOID
EGR SOLENOID (CALIFORNIA)
FUEL INJECTORS
ALTERNATOR
BAROMETRIC SOLENOID
LOCK-UP TORQUE CONVERTER SOLENOID
SPEED CONTROL SOLENOIDS
RADIATOR FAN RELAY
A/C CUTOUT RELAY
AUTO SHUTDOWN RELAY
TACHOMETER

Fig. 24-4. Computerized engine control components govern engine operating conditions. Note specific input and output devices. (Chrysler)

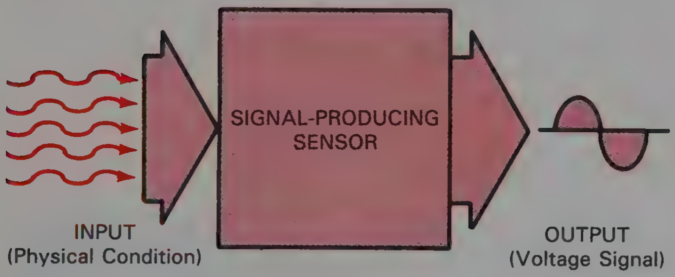

SIGNAL-PRODUCING SENSOR
INPUT (Physical Condition)
OUTPUT (Voltage Signal)

Fig. 24-5. Signal-producing sensors generate a small voltage signal that varies as operating conditions change.

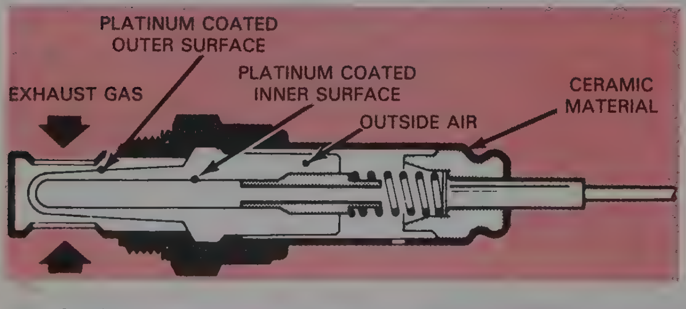

PLATINUM COATED OUTER SURFACE
PLATINUM COATED INNER SURFACE
EXHAUST GAS
OUTSIDE AIR
CERAMIC MATERIAL

Fig. 24-6. Cross section of an oxygen sensor. Voltage signals from the sensor are sent to the electronic control unit. This particular sensor must be heated to 600 °F (315 °C) before it will produce a signal. (Sun)

sending output signals, it is operating in the closed loop state, Fig. 24-7A. If this cycle is broken, the system goes into the open loop state. When in open loop, the computer does not control operating conditions within a vehicle, Fig. 24-7B.

Most computer control systems rely on the oxygen sensor to govern loop operation. If the sensor's temperature is below 600°F (315°C), it will not produce a signal and the system will remain in an open loop state. Once the sensor reaches the correct operating temperature, it will send a signal to the ECU and the system will begin closed loop operation.

ENGINE SPEED SENSORS

Engine speed sensors provide the electronic control unit with information about engine speed (rpm) and piston position. The ECU uses this information to calculate ignition timing and fuel injection timing. These sensors monitor crankshaft or distributor shaft rotation, Fig. 24-8 and Fig. 24-9. A magnetic field, which is produced by the rotation of the crankshaft (or distributor shaft), creates a voltage signal in the sensor. The strength of this signal varies in relation to the speed of shaft rotation. A camshaft position sensor

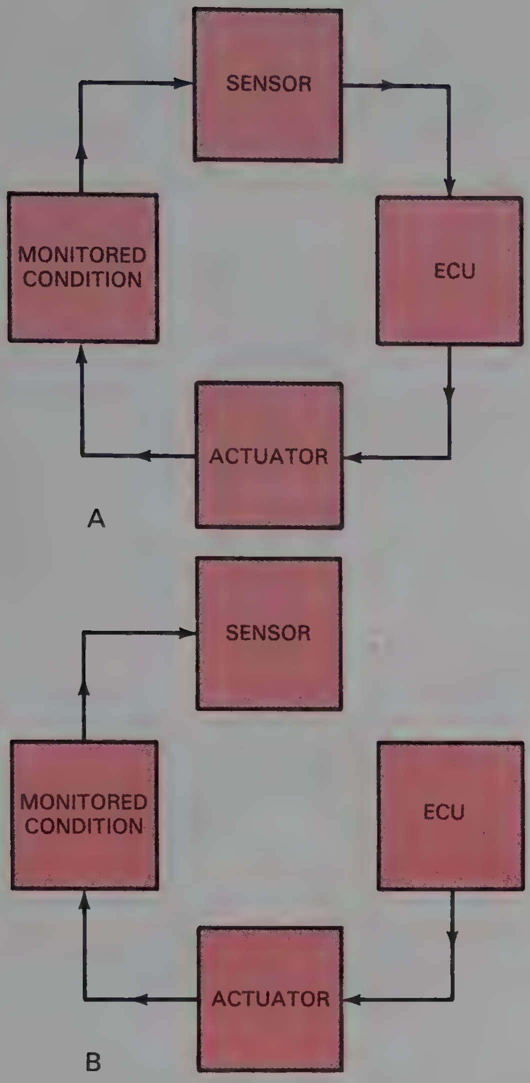

SENSOR
MONITORED CONDITION
ECU
ACTUATOR
A
SENSOR
MONITORED CONDITION
ECU
ACTUATOR
B

Fig. 24-7. A—When computer control system is operating in the closed loop state, ECU receives signals from the sensor. B—If sensor does not produce a signal, ECU cannot control operating conditions.

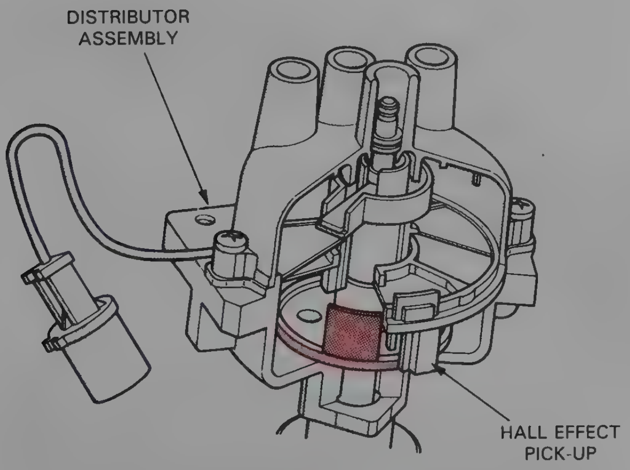

DISTRIBUTOR ASSEMBLY
HALL EFFECT PICK-UP

Fig. 24-8. This engine speed sensor monitors distributor shaft rotation. As shaft turns, voltage is produced in the sensor. (Chrysler)

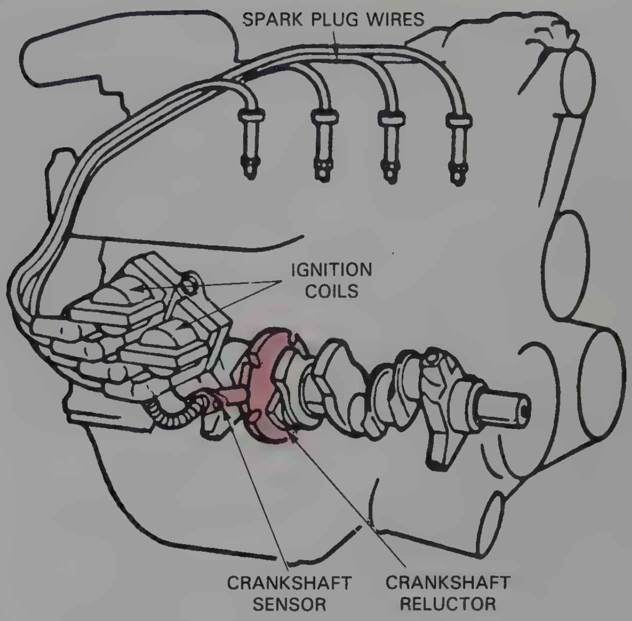

SPARK PLUG WIRES
IGNITION COILS
CRANKSHAFT SENSOR
CRANKSHAFT RELUCTOR

Fig. 24-9. Engine speed sensor that monitors rotation of the crankshaft. Note that sensor is mounted to the engine block and reluctor is attached to the crankshaft. (Chevrolet)

works on the same principles as the crankshaft sensor, but it monitors camshaft rotation.

DETONATION SENSORS

A detonation sensor is used to alert the electronic control unit of engine pinging and knocking. It converts abnormal engine vibrations into electrical signals. Upon receiving signals from the detonation sensor, the electronic control unit can retard the ignition timing to correct the condition. A detonation sensor is shown in Fig. 24-10.

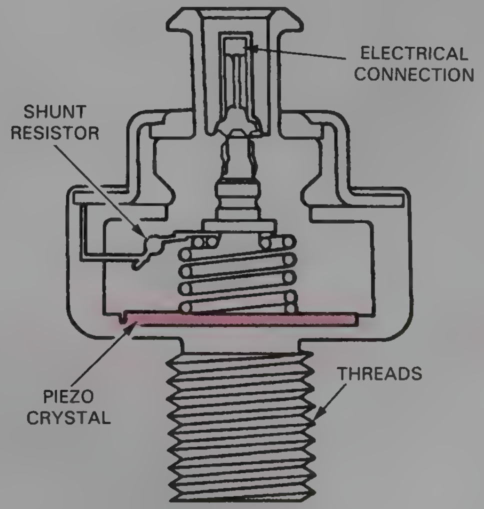

ELECTRICAL CONNECTION
SHUNT RESISTOR
THREADS
PIEZO CRYSTAL

Fig. 24-10. Detonation sensor converts engine pinging and knocking into electrical signals. This sensor mounts in the engine block. (Buick)

SIGNAL-MODIFYING SENSORS

Some sensors do not have the ability to produce a voltage signal and must rely on a reference voltage supplied by the electronic control unit. The reference voltage, which is usually 5 volts, is modified by the sensor and sent back to the ECU, Fig. 24-11. The control unit analyzes the changes in reference voltage and makes adjustments accordingly. Most signal-modifying sensors change the reference voltage by varying their resistance in response to changes in engine operating conditions. As the resistance of the sensor changes, the output voltage of the sensor circuit changes. Typical signal-modifying sensors include:

1. Coolant temperature sensors.
2. Manifold air temperature sensors.
3. Throttle position sensors.
4. Manifold absolute pressure sensor.
5. Airflow sensors.

COOLANT TEMPERATURE SENSOR

As its name implies, the coolant temperature sensor monitors the temperature of the engine coolant. The tip of this sensor is exposed to the engine coolant. The sensor varies its internal resistance as the temperature of the coolant changes. The electronic control unit uses the output signal from the coolant temperature sensor circuit to calculate the appropriate air-fuel mixture for cold or warm operating conditions. Fig. 24-12 illustrates a typical coolant temperature sensor.

MANIFOLD AIR TEMPERATURE SENSOR

The manifold air temperature (MAT) sensor measures the temperature of the air entering the intake manifold, Fig. 24-13. As intake air temperature changes, the internal resistance of the sensor changes. This change in resistance varies the voltage signal that the sensor returns to the electronic control unit. The ECU uses the output signal from the MAT sensor circuit to help determine the optimal air-fuel mixture. As intake air gets warmer, less fuel is needed to operate the engine efficiently.

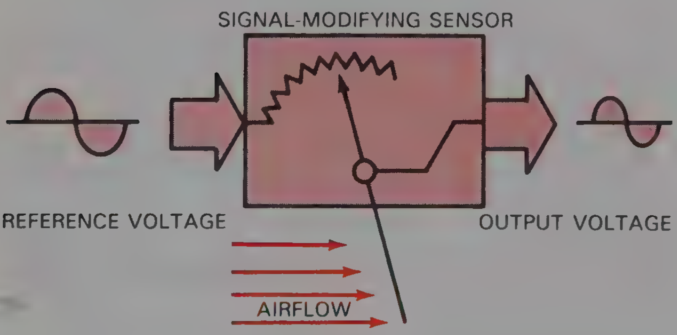


Fig. 24-11. Typical signal-modifying sensor. This particular sensor varies its resistance as airflow changes.

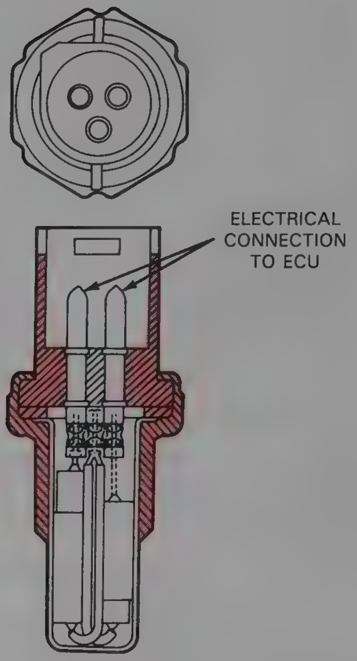


Fig. 24-12. Typical coolant temperature sensor. This sensor is generally mounted near thermostat housing. (Ford)

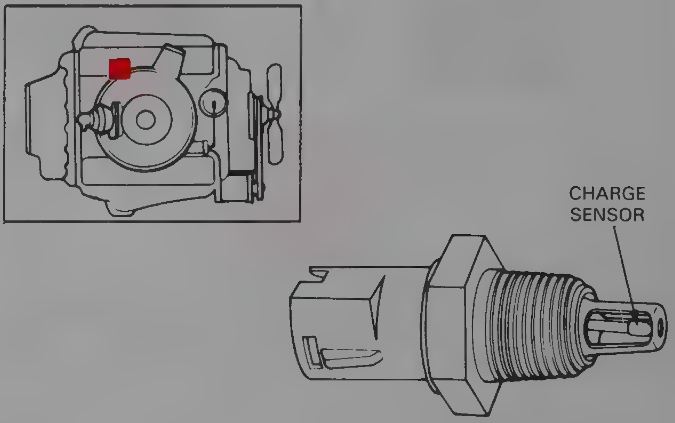


Fig. 24-13. Manifold air temperature sensor monitors the temperature of air entering intake manifold. This sensor is commonly mounted in the air cleaner housing near the throttle body or intake manifold. (Chrysler)

THROTTLE POSITION SENSOR

The throttle position sensor (TPS) is one of the only computer control components that is mechanical in nature. The TPS monitors the position of the throttle valve. The sensor changes its resistance in relation to the position of the throttle shaft. When the throttle is closed, the output signal from the TPS circuit is low. The TPS circuit output voltage rises proportionally as the throttle is opened. A typical throttle position sensor is illustrated in Fig. 24-14. The computer uses the signals from the TPS circuit to control ignition timing, fuel delivery, and EGR valve position.

MANIFOLD ABSOLUTE PRESSURE SENSOR

The manifold absolute pressure (MAP) sensor monitors changes in the engine's intake manifold pressure, Fig. 24-15. As the manifold pressure changes, the sensor's internal resistance varies. The ECU uses the output signal from the MAP sensor circuit to help calculate the correct amount of fuel entering the engine.

FLAP AIRFLOW SENSORS

Flap airflow sensors monitor the amount of air entering a vehicle's throttle body or carburetor. This sensor utilizes a pivoting flap, which is connected to a variable resistor, Fig. 24-16. As the amount of air flowing through the sensor varies, the flap moves and the resistance of the sensor changes. This change in resistance alters the reference voltage. The output from the flap airflow sensor circuit is used to help calculate the proper air-fuel mixture.

MASS AIRFLOW SENSOR

The mass airflow sensor, like a flap airflow sensor, is used to measure the volume of air entering the engine, Fig. 24-17. This sensor, however, has the ability to com-

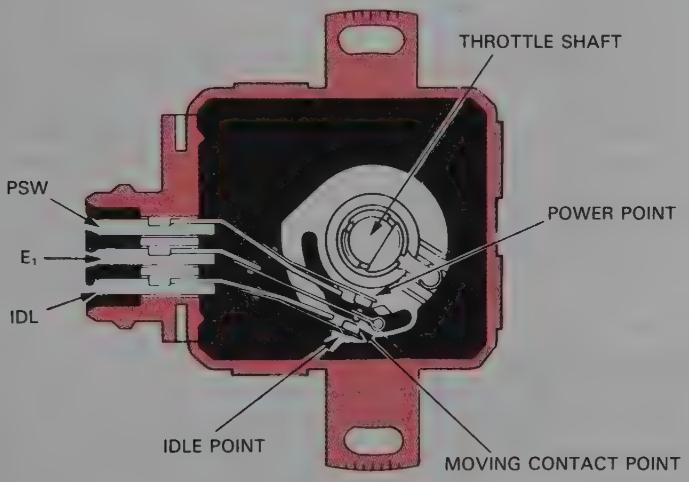

THROTTLE SHAFT
PSW
POWER POINT
E_1
IDL
IDLE POINT
MOVING CONTACT POINT

Fig. 24-14. Cutaway view of a throttle position sensor. As throttle shaft moves, resistance of sensor changes. (Toyota)

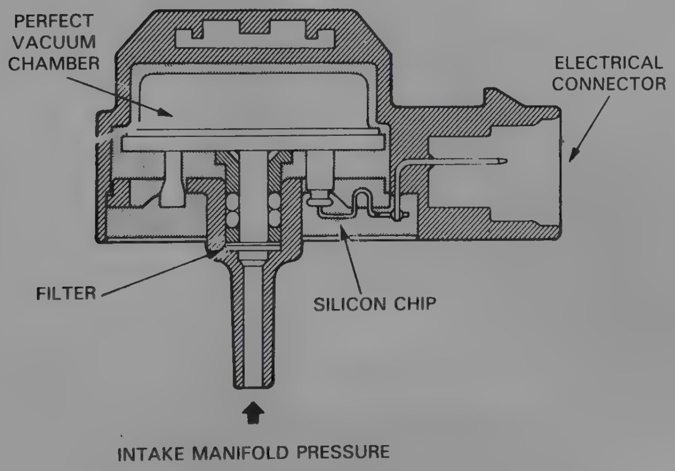

PERFECT VACUUM CHAMBER
ELECTRICAL CONNECTOR
FILTER
SILICON CHIP
INTAKE MANIFOLD PRESSURE

Fig. 24-15. Cutaway view of a manifold absolute pressure sensor. Note hookup for vacuum hose and electrical connector. (Toyota)

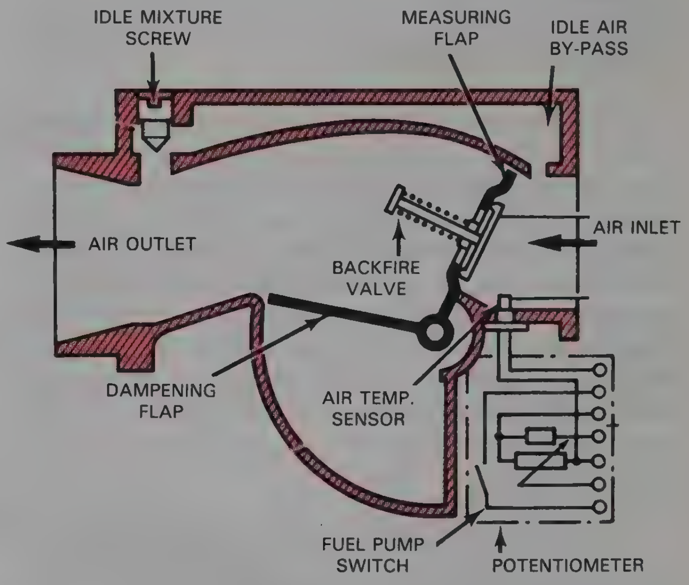

IDLE MIXTURE SCREW
MEASURING FLAP
IDLE AIR BY-PASS
AIR OUTLET
AIR INLET
BACKFIRE VALVE
DAMPENING FLAP
AIR TEMP. SENSOR
FUEL PUMP SWITCH
POTENTIOMETER

Fig. 24-16. Cutaway view of a flap airflow sensor assembly. Note air temperature sensor and idle air by-pass. (Bosch)

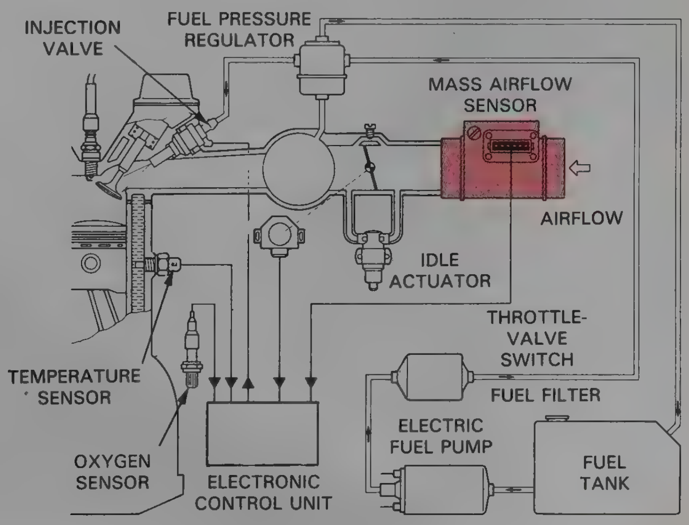

INJECTION VALVE
FUEL PRESSURE REGULATOR
MASS AIRFLOW SENSOR
AIRFLOW
IDLE ACTUATOR
THROTTLE-VALVE SWITCH
TEMPERATURE SENSOR
FUEL FILTER
ELECTRIC FUEL PUMP
OXYGEN SENSOR
ELECTRONIC CONTROL UNIT
FUEL TANK

Fig. 24-17. Schematic diagram of an engine control system containing a mass airflow sensor. An air temperature sensor and a barometric pressure sensor are not required in this system. (Bosch)

pensate for changes in air temperature and atmospheric pressure. Therefore, the need for an air temperature sensor and a barometric pressure sensor is eliminated in systems using a mass airflow sensor.

A mass airflow sensor uses a wire screen, located in the airflow path, to monitor the amount of air entering the intake manifold. The screen is heated by a reference voltage, which is supplied by the electronic control unit. As air flows through the screen, its temperature is reduced. As the temperature drops, the ECU increases the reference voltage to maintain a constant temperature at the screen. The ECU analyzes reference voltage changes and calculates the rate of airflow. The ECU then adjusts the air-fuel ratio to compensate for changes in airflow.

SWITCHING SENSORS

Computer control systems use several switching sensors to monitor certain engine operating conditions. These sensors simply turn on and off in response to specific situations. Some sensors use an internal pressure-sensing element to monitor these situations, Fig. 24-18. Many switching sensors are physically switched on and off by moving parts within the monitored circuit. Switching sensors are considered to be passive transducers because they modify a reference voltage that they receive from the ECU.

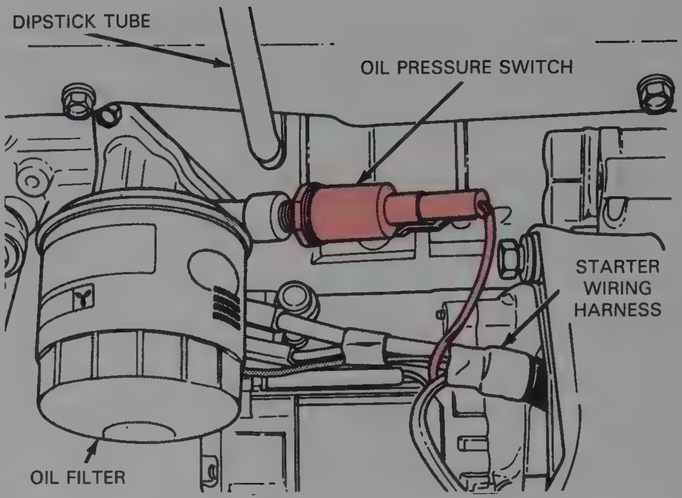


Fig. 24-18. Oil pressure switch is a typical switching sensor. When pressure drops below a certain point, this sensor switches on to alert ECU of condition. (Chrysler)

ELECTRONIC CONTROL UNIT OPERATION

The electronic control unit (ECU) is a very complex device. It is housed in a box-like casing and is constructed from a number of integrated circuits, printed circuit boards, and other electronic components. Fig. 24-19 illustrates a typical electronic control unit.

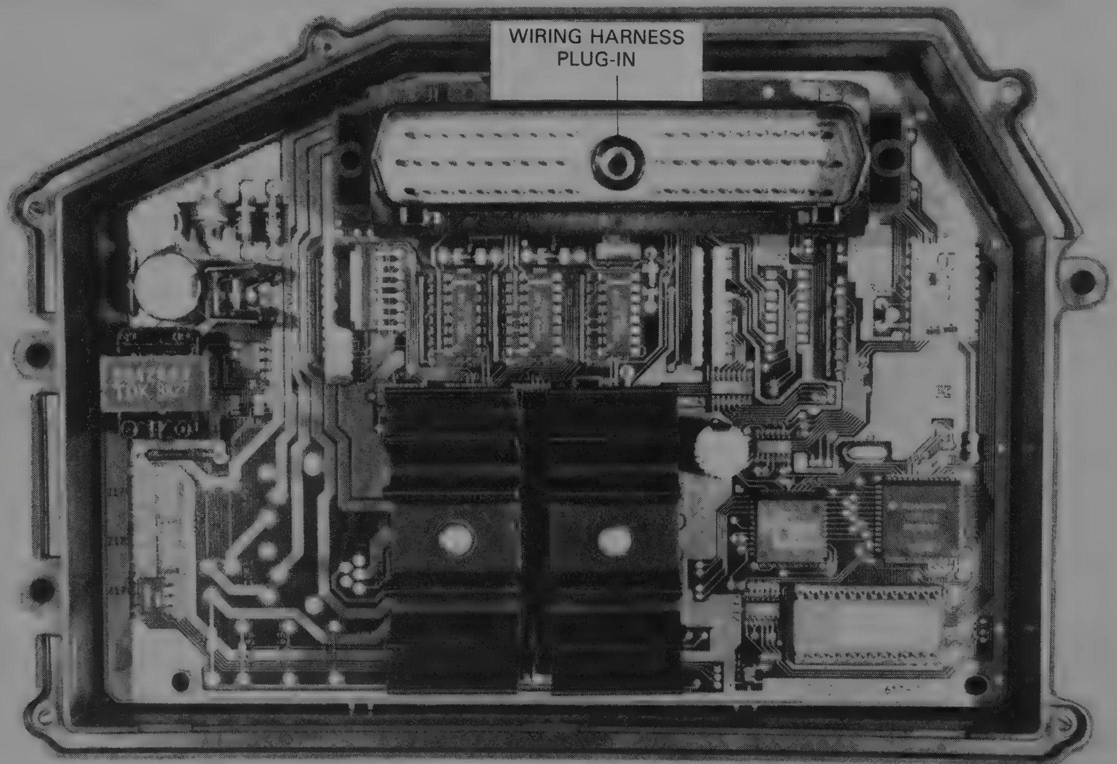


Fig. 24-19. View of electronic components inside one type of electronic control unit. Electronic control units cannot be serviced in the field. (Chrysler)

It is not necessary to know how the internal components of the ECU work. It is helpful, however, to understand the basic operation of the unit in order to effectively troubleshoot a computer control system.

The ECU can be divided into five basic sections: the input section, the memory section, the arithmetic/logic section, the control section, and the output section. Each section performs a specific function within the unit. See Fig. 24-20.

INPUT SECTION

The input section of the electronic control unit allows sensors to communicate with the other sections in the unit. Input signals often reach the ECU in a form that it cannot process. The input section converts sensor signals to a form that the computer can use.

MEMORY SECTION

The electronic control unit's memory section stores data until it is needed for processing operations. The three types of memory commonly used in automobile computer systems include ROM (read only memory), RAM (random access memory), and PROM (programmable read only memory). Each memory type performs a specific function in the computer's memory system.

ROM

ROM (read only memory) is used to store the computer's operating instructions (programs). It also stores general information that tells the computer how various components should perform under specific operating conditions. As its name implies, data in ROM can only be read. The information in ROM can never be modified. The contents in ROM will not be lost if power to the computer is disconnected. The data stored in ROM is universal, and, therefore, a manufacturer can use the same ROM memory for an entire product line. The electronic control unit compares data stored in ROM to input information from the sensors. If the result of the comparison is not within acceptable parameters, the ECU will take action to change operating conditions.

RAM

RAM (random access memory) is used as a temporary storage place for data from the sensors. The electronic control unit uses the information stored in RAM to analyze specific operating conditions. RAM is also used to store trouble codes when abnormal operating conditions occur. Trouble codes will be covered in detail later in this chapter. RAM is considered to be a volatile memory because its contents will be lost if battery voltage is disconnected from the computer.

PROM

PROM, like ROM, contains permanent information about how components should perform under various operating conditions. The information in PROM, however, is much more specific than the data stored in ROM. The information in PROM depends on a vehicle's options. For example, a vehicle with an automatic transmission would have a different PROM than an identical vehicle with a standard transmission. The PROM is the only part of the electronic control unit that can be serviced in the field.

ARITHMETIC/LOGIC SECTION

The arithmetic/logic section of the electronic control unit analyzes input information and calculates output data. In addition to making mathematical calculations, the arithmetic/logic section uses logic to make output decisions. For example, when the ECU receives input from the oxygen sensor, it is routed to the arithmetic/logic section where it is compared to a preset value stored in the computer's memory. The

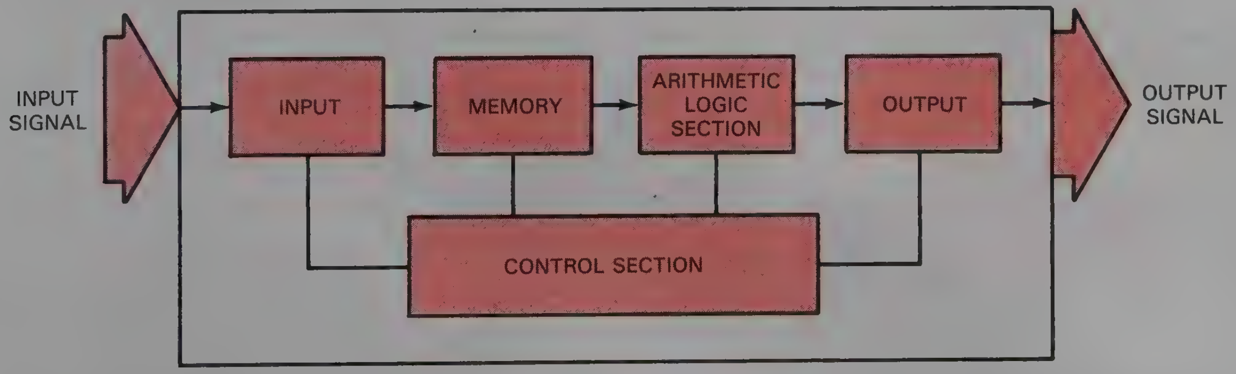


Fig. 24-20. Electronic control unit can be divided into five sections. Each section performs a specific function within the unit.

arithmetic/logic section determines if the value received from the sensor is greater than, less than, or equal to the value stored in the ECU's memory.

CONTROL SECTION

The control section governs all of the other sections in the computer. For example, the control section can instruct the arithmetic/logic section to compare the input from a specific sensor to the ideal value stored in ROM.

OUTPUT SECTION

The function of the electronic control unit's output section is similar to the function of the input section. This section converts the computer's output signal to a form that an output device can use to produce an appropriate control function.

ACTUATORS

Actuators convert electrical output signals, sent by the electronic control unit, into physical movements, Fig. 24-21. The ECU uses actuators to make physical adjustments that change operating conditions. Commonly used actuators include:

1. Fuel injectors.
2. Idle speed motors.
3. Mixture control solenoids.
4. Electric fan relays.

FUEL INJECTORS

A fuel injector is an actuator that meters the amount of fuel injected into the throttle body or cylinders, Fig. 24-22. When the computer energizes the injector, a sealing needle is lifted from its seat, allowing fuel to spray out. When the computer signal stops, spring pressure will force the needle valve closed. Fuel injector operation is explained in detail in Chapter 22.

IDLE SPEED MOTOR

The computer uses the idle speed motor to increase idle speed when the engine is under a heavy load. This actuator increases idle speed by moving the throttle lever. A load, such as an air conditioning compressor, can cause the engine to stall if the idle speed sensor is not working properly. A typical idle speed motor is illustrated in Fig. 24-23.

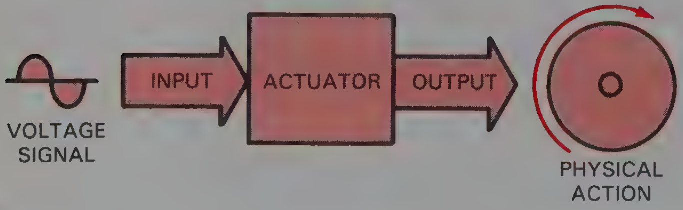


Fig. 24-21. Actuators convert output signals from the electronic control unit into physical actions. Most actuators are motors, solenoids, or relays.

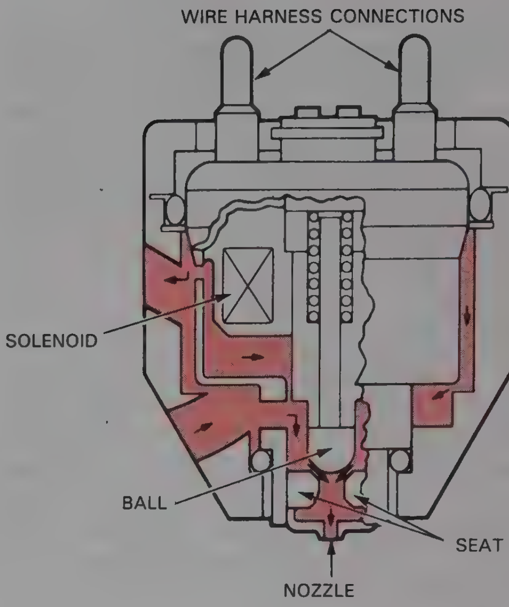


Fig. 24-22. Sectional view of a fuel injector used in a throttle body assembly. When this injector is energized, ball is lifted from seat and fuel is sprayed from nozzle. (Chrysler)

MIXTURE CONTROL SOLENOID

The mixture control solenoid is only used on engines equipped with carburetors. When this actuator is energized, the solenoid moves the carburetor's metering rod in and out of the metering jet. The mixture control solenoid is typically cycled on and off several times a second. A mixture control solenoid is shown in Fig. 24-24.

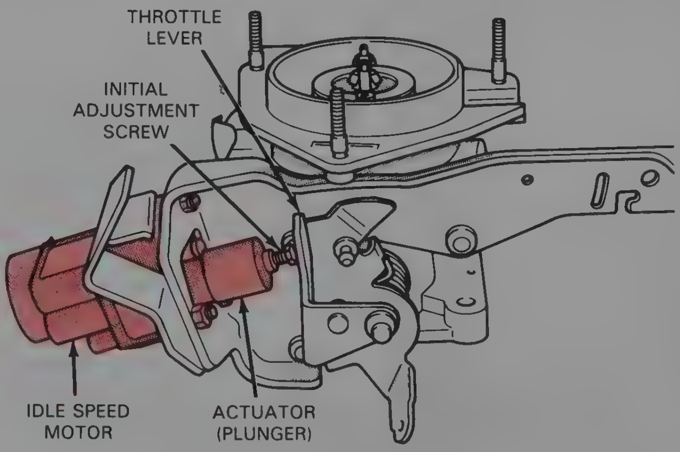


Fig. 24-23. Idle speed motor assembly. Note that actuator just touches throttle lever when in the retracted position. (Jeep)

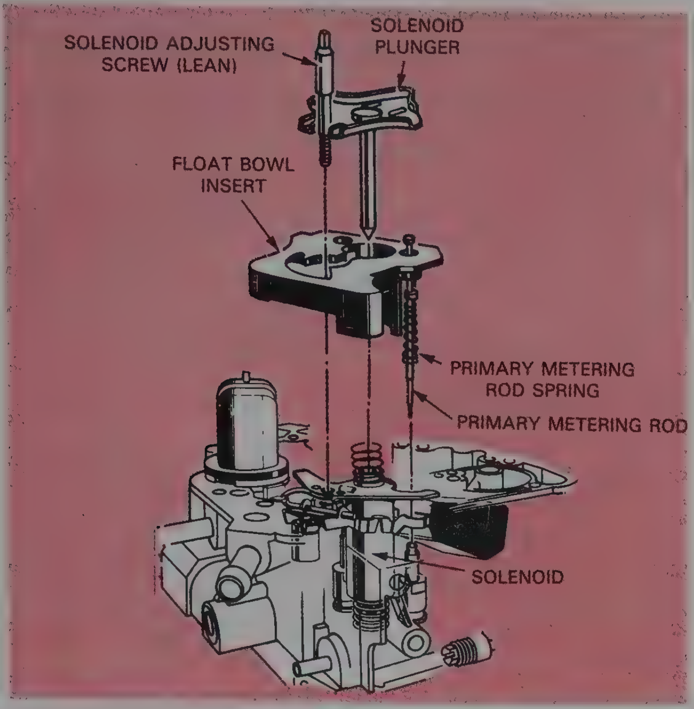

SOLENOID ADJUSTING SCREW (LEAN)
SOLENOID PLUNGER
FLOAT BOWL INSERT
PRIMARY METERING ROD SPRING
PRIMARY METERING ROD
SOLENOID

Fig. 24-24. Exploded view of a carburetor mixture-control solenoid unit. (Chevrolet)

ELECTRIC FAN RELAY

When engine coolant temperature reaches approximately 226°F (108°C), the computer energizes the electric fan relay. This relay activates the electric fan motor. Some fan relays are automatically activated each time the air conditioner is switched on. The wiring schematic for a specific fan relay circuit is shown in Fig. 24-25.

TROUBLESHOOTING — A LOGICAL APPROACH

A thorough understanding of basic computer control system operation is necessary to effectively troubleshoot computer control systems. A logical approach must be taken when attempting to locate a problem. There are many sophisticated procedures involved in testing computer control systems. It is not within the scope of this text to explain every possible testing method. Therefore, a general overview of the most common testing procedures is presented in the following sections. They are designed to provide the background information necessary to effectively use the diagnostic resources available when servicing computerized control systems.

Even a trained technician cannot expect to learn enough about these complex systems to solve problems on his own. Today's automotive technicians must rely on the information found in manuals, diagnostic charts, and other service publications when troubleshooting computer control systems.

SELF-DIAGNOSTIC SYSTEMS

Although computer control systems precisely control various operating conditions in the automobile, they are often very difficult to service. To aid the technician in troubleshooting the computer system, manufacturers have designed self-diagnostic systems into their products. These systems continuously monitor the operation of the sensors, the actuators, and the ECU. If an abnormal condition is detected, a warning signal is placed in the electronic control unit's memory.

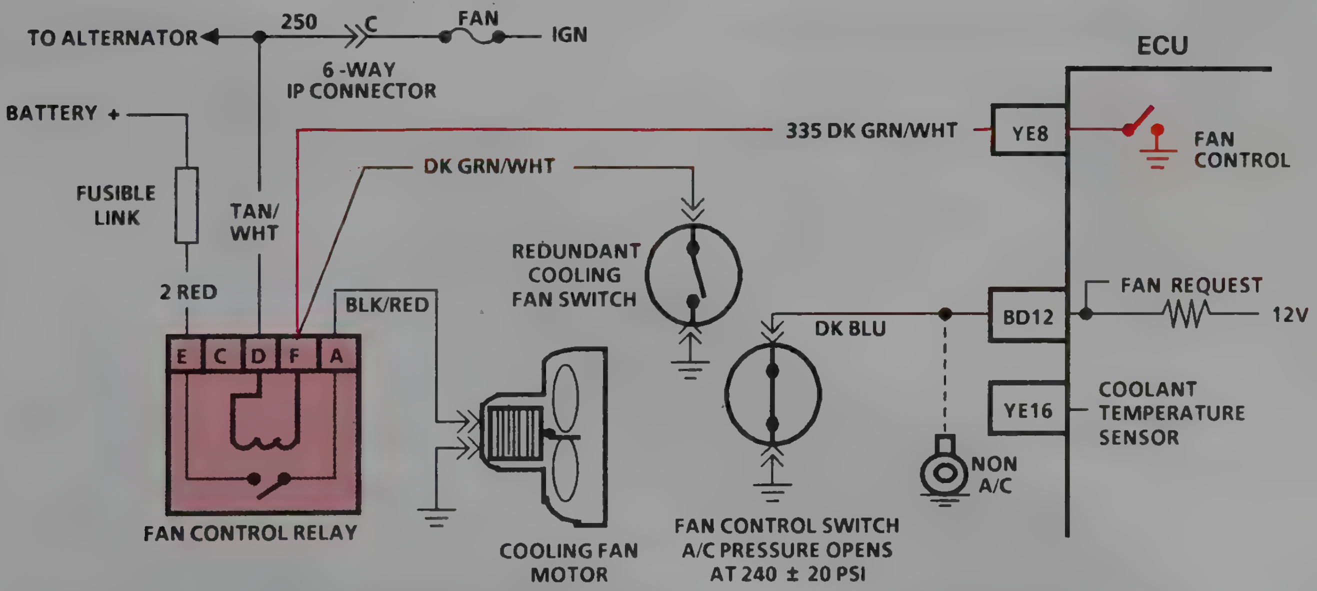

TO ALTERNATOR
250
C
FAN
IGN
6-WAY IP CONNECTOR
BATTERY +
FUSIBLE LINK
TAN/ WHT
2 RED
335 DK GRN/WHT
DK GRN/WHT
BLK/RED
E C D F A
FAN CONTROL RELAY
REDUNDANT COOLING FAN SWITCH
COOLING FAN MOTOR
DK BLU
FAN CONTROL SWITCH A/C PRESSURE OPENS AT 240 ± 20 PSI
NON A/C
ECU
YE8
FAN CONTROL
BD12
FAN REQUEST
12V
YE16
COOLANT TEMPERATURE SENSOR

Fig. 24-25. Schematic diagram of an electric cooling fan relay circuit. Electronic control unit grounds sensor circuit to trigger relay. (Pontiac)

Self-diagnostic capabilities have been a tremendous help to the automotive technician. It is very important to be able to use these features effectively.

TROUBLE CODES

When the electronic control unit's self-diagnostic system detects an abnormal operating condition, it places a warning signal into the unit's memory. These signals are called trouble codes. Whenever a trouble code is stored in memory, a warning light is activated on the vehicle's dashboard, Fig. 24-26. The *service engine soon* or *check engine* light is often used for this purpose. The warning light alerts the driver to the fact that a problem exists and the vehicle requires service.

ACTIVATING SELF-DIAGNOSTIC SYSTEMS

If the warning light remains on when the engine is running, the technician can assume that there is at least one trouble code stored in the electronic control unit's memory. In order to retrieve stored trouble codes, the technician must prompt the ECU's self-diagnostic system to release them from memory. Methods for extracting trouble codes vary. Some systems simply require connecting test leads across individual pins of a diagnostic link. Others require the use of special testing equipment. The most common methods of retrieving trouble codes from the computer's memory include the following:

1. Switching a control mode selector on the side of the electronic control unit.
2. Turning the ignition switch on and off several times in a specified period of time.
3. Connecting a voltmeter to one or more terminals of the diagnostic test link.
4. Grounding one of the terminals on the diagnostic test link.
5. Connecting two specific diagnostic test link terminals.

These are only a few examples of the possible methods for retrieving trouble codes. Always consult an appropriate service manual to determine which method is correct for the vehicle at hand. The wrong test hookup or grounding incorrect terminals can destroy fragile computer system components.

DIAGNOSTIC LINK

Many vehicles are equipped with a special diagnostic link, which is used to check the computer control system at the factory. These multi-pin terminals also serve as connecting points for test equipment in the field. The diagnostic link can be located in various sections of the automobile, Fig. 24-27. Common locations include:

1. Under the glove compartment.
2. Under the steering column.
3. In the engine compartment (on fire wall or wheel well).

Some manufacturers refer to the diagnostic link as an assembly line diagnostic link (ALDL) or as a self-test connector.

READING TROUBLE CODES

Once the self-diagnostic system has been activated, the computer will release the stored trouble codes. The codes can be displayed in several ways. Always refer to the service manual for information on how to read

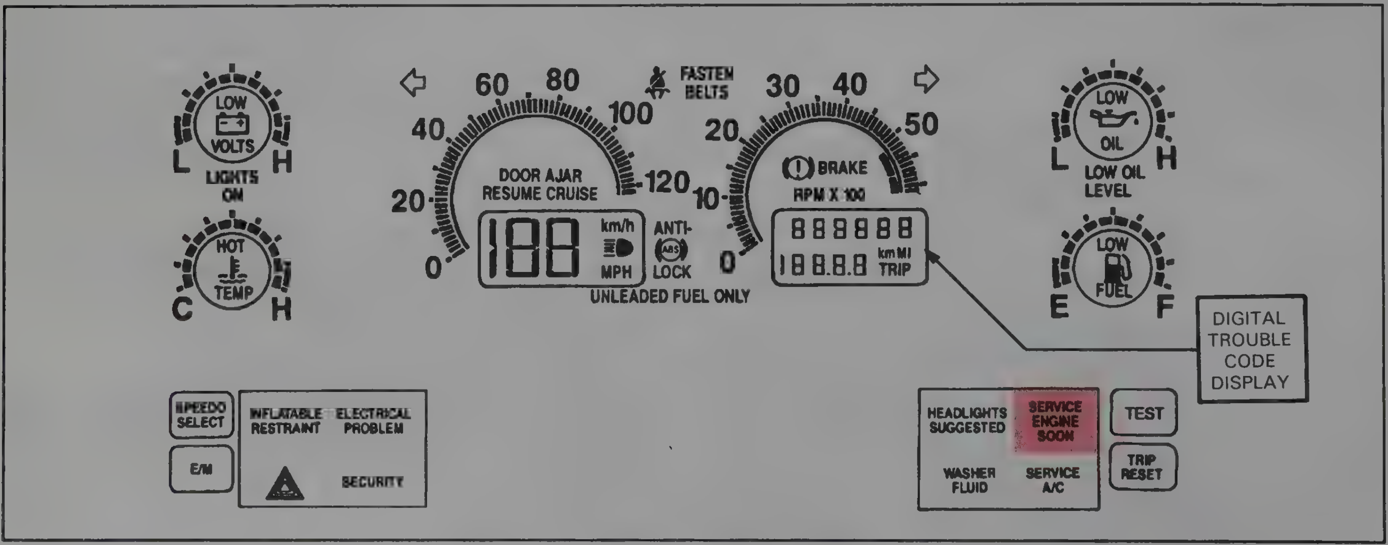

LOW VOLTS
L
H
LIGHTS ON
HOT
TEMP
C
H
60
80
40
100
20
120
0
DOOR AJAR
RESUME CRUISE
188
km/h
MPH
ANTI-LOCK
UNLEADED FUEL ONLY
FASTEN BELTS
30
40
20
50
10
0
BRAKE
RPM X 100
888888
188.8.8
km MI
TRIP
LOW OIL
L
H
LOW OIL LEVEL
LOW FUEL
E
F
DIGITAL TROUBLE CODE DISPLAY
SPEEDO SELECT
E/M
INFLATABLE RESTRAINT
ELECTRICAL PROBLEM
SECURITY
HEADLIGHTS SUGGESTED
SERVICE ENGINE SOON
WASHER FLUID
SERVICE A/C
TEST
TRIP RESET

Fig. 24-26. The check engine or service engine soon light is often used to alert driver to a problem in computer control system. The light will remain on if there is a trouble code stored in the computer's memory. Note that trouble codes in this system are digitally displayed on the vehicle's dashboard. (Buick)

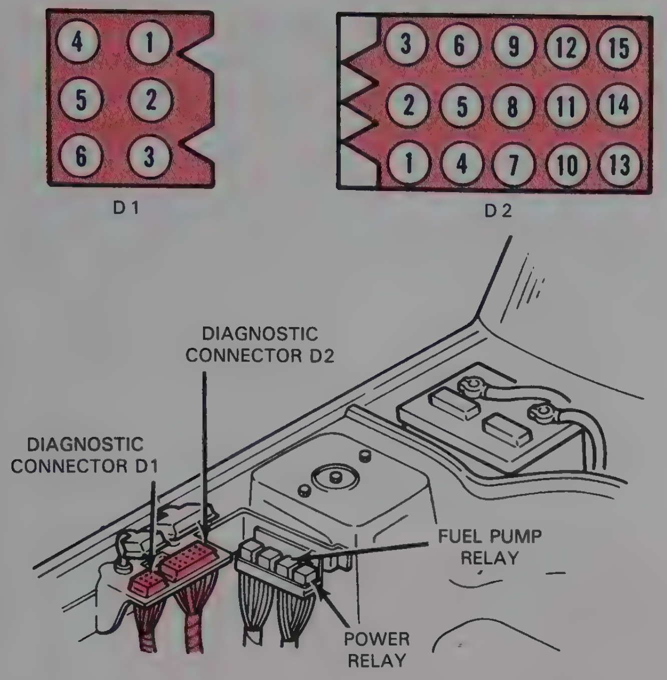


Fig. 24-27. One type of diagnostic link located on wheel well. This vehicle is equipped with two separate diagnostic connectors. Note caps that protect connectors when they are not being used. (Chrysler)

trouble codes for the system at hand. Some typical ways that these codes are displayed include:

1. Counting flashing warning light.
2. Counting meter needle sweeps.
3. Observing digital dash readout.

FLASHING WARNING LIGHT

A flashing warning light is one of the most common methods used to display trouble codes. The technician simply counts the flashes produced by a warning light (check engine or service engine soon) in the vehicle's dashboard. The number of flashes represents the trouble code stored in memory. For example, if the trouble code is 3, the light will flash three consecutive times. If there is more than one code in memory, there will be a 2.5 second pause before the second code is displayed. Some systems are set up to display two digit trouble codes. In these systems, the light flashes the first digit, pauses for 1.5 seconds, and then flashes the second digit. Again, when more than one code is stored in memory, there will be a 2.5 second pause between codes. A two digit trouble code is illustrated in Fig. 24-28.

ANALOG METER SWEEPS

Some systems require the use of an analog voltmeter to retrieve trouble codes. The meter's needle "sweeps" for each digit of the trouble code. The code is counted in a manner similar to the flashing warning light. For a single digit trouble code, such as five, the needle would sweep five consecutive times. If the code is a two digit number, such as 12, the needle would sweep once, pause for approximately 1.5 seconds, and sweep two more times.

DIGITAL DASH READOUT

Some highly technical self-diagnostic systems display trouble codes directly onto a screen mounted in the vehicle's instrument panel. See Fig. 24-26. This method eliminates the possibility of error from misinterpreting flashing codes or analog meter sweeps. Most digital display systems are activated by simply pressing designated instrument controls simultaneously until an audible signal is detected. In addition to the ability to troubleshoot the entire computer control system, many digital self-diagnostic systems can perform specialized tests. For example, most of these systems have the ability to measure and record the voltage signals sent by individual sensors.

USING TROUBLE CODE CHARTS

Once the trouble codes have been obtained, the technician must compare the code numbers to a trouble code chart. The trouble code chart contains infor-

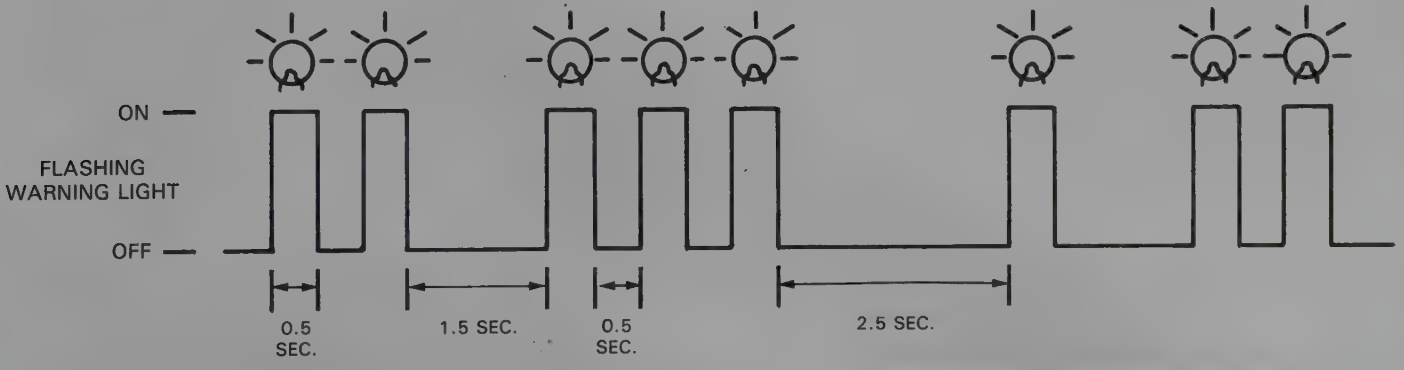


Fig. 24-28. Trouble codes are often displayed with flashing warning lights. Note 1.5 second pause between digits of two digit codes and 2.5 second pause between individual codes. Trouble codes 23 and 12 are represented here.

mation about the meaning of each trouble code. This information can be used as a starting point in the troubleshooting process. Most trouble codes indicate which circuit a problem is detected in. For example, in some systems the trouble code 21 represents a malfunction in the oxygen sensor circuit, Fig. 24-29.

Code No.	Item	Diagnosis	Trouble Area	"CHECK ENGINE" Lamp
12	RPM Signal	No "Ne" or "G" signal to ECU within 2 seconds after the engine has been cranked.	• Distributor circuit • Distributor • Starter signal circuit • ECU	ON
13	RPM Signal	No "Ne" signal to ECU when the engine speed is above 1000 rpm.	• Distributor circuit • Distributor • ECU	ON
14	Ignition Signal	No "IGf" signal to ECU 8 ~ 11 times in succession.	• Igniter and ignition coil circuit • Igniter and ignition coil • ECU	ON
21	Oxygen Sensor Signal	During air-fuel ratio feedback correction, voltage output from the oxygen sensor does not exceed a set value on the lean side and the rich side continuously for a certain period.	• Oxygen sensor circuit • Oxygen sensor	ON
	Oxygen Sensor Heater Signal	Open or short circuit in oxygen sensor heater signal (HT).	• Oxygen sensor heater circuit • Oxygen sensor heater • ECU	
22	Water Temp. Sensor Signal	Open or short circuit in water temp. sensor signal (THW).	• Water temp. sensor circuit • Water temp. sensor • ECU	ON
24	Intake Air Temp. Sensor Signal	Open or short circuit in intake air temp. sensor signal (THA).	• Intake air temp. sensor circuit • Intake air temp. sensor • ECU	ON*
25	Air-fuel Ratio Lean Malfunction	(1)* When air-fuel ratio feedback correction value or adaptive control value continues at the upper (lean) or lower (rich) limit renewed for a certain period of time. (2)* When air-fuel ratio feedback correction value or adaptive control value feedback frequency is abnormally high during feedback condition. (3) Open or short circuit in oxygen sensor signal.	• Injector ciucuit • Injector • Fuel line pressure • Ignition system • Oxygen sensor circuit • Oxygen sensor • Air flow meter • Water temp. sensor • ECU	ON ON*
26	Air-fuel Ratio Rich Malfunction		• Injector circuit • Injector • Fuel line pressure • Cold start injector • Air flow meter • Water temp. sensor • ECU	ON*
31	Air Flow Meter Signal	Open circuit in V_C signal or short circuit between V_C and E_2 when idle contacts are closed.	• Air flow meter circuit • Air flow meter • ECU	ON
32	Air Flow Meter Signal	Open circuit in E_2 or short circuit between V_C and V_S.	• Air flow meter circuit • Air flow meter • ECU	ON
34	Turbocharging Pressure Signal	Excessive turbocharging pressure.	• Turbocharger • Turbocharging pressure sensor circuit • Turbocharging pressure sensor • ECU	ON
35	Turbocharging Pressure Sensor Signal	Open or short circuit in turbocharging pressure sensor signal (PIM).	• Turbocharging pressure sensor circuit • Turbocharging pressure sensor • ECU	OFF

*Applicable only to California specification vehicles.

Fig. 24-29. Once trouble codes have been extracted, the technician can use a trouble code chart to determine what codes represent. Codes usually indicate circuit malfunctions and do not pinpoint specific problems. (Toyota)

SCAN TOOLS

A diagnostic scan tool is often used to retrieve trouble codes, Fig. 24-30. Most scan tools convert the codes directly into a digital display. Scan tools do not have the ability to pinpoint problems within a circuit. Many scan tools, however, have the capability to record the signal values that the electronic control unit receives from the sensors. This eliminates the need to check each sensor individually.

DIAGNOSTIC ANALYZERS

Modern diagnostic analyzers can be used to troubleshoot computer control systems. Most analyzers connect directly to the vehicle's diagnostic link. The analyzer uses information from the sensors and the electronic control unit to determine if the system is operating properly. Many analyzers have the ability to supply the technician with troubleshooting and repair instructions based on these values. Some systems are so sophisticated that they can communicate with a mainframe computer at a remote location. One type of diagnostic analyzer is illustrated in Fig. 24-31.

USING DIAGNOSTIC INFORMATION

Trouble codes indicate the circuit or area that is operating improperly. Most codes, however, do not pinpoint the exact cause of the problem. The trouble could be a shorted wire, a loose connection, a faulty sensor, actuator, or control unit. Once a trouble code has been obtained, it is often necessary for the technician to perform a series of specialized tests to locate the faulty component(s) within a circuit. These procedures are often referred to as pinpoint tests.

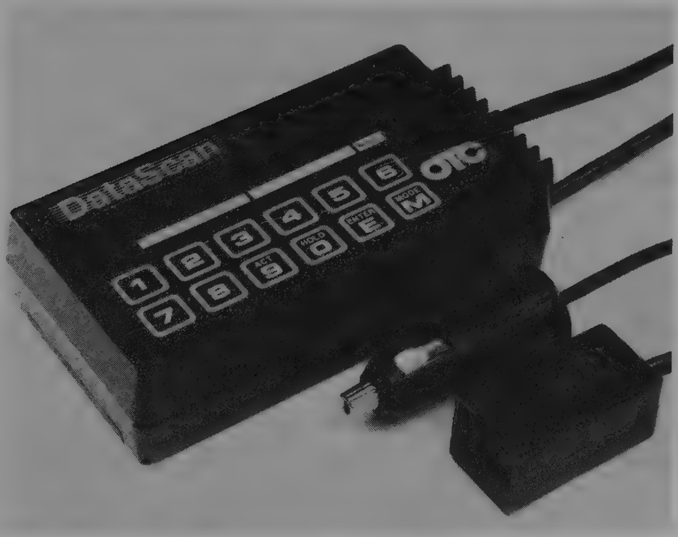


Fig. 24-30. Many manufacturers recommend the use of a scan tool to record signals from individual computer control system components. Always follow instructions when connecting any testing device in electronic systems.

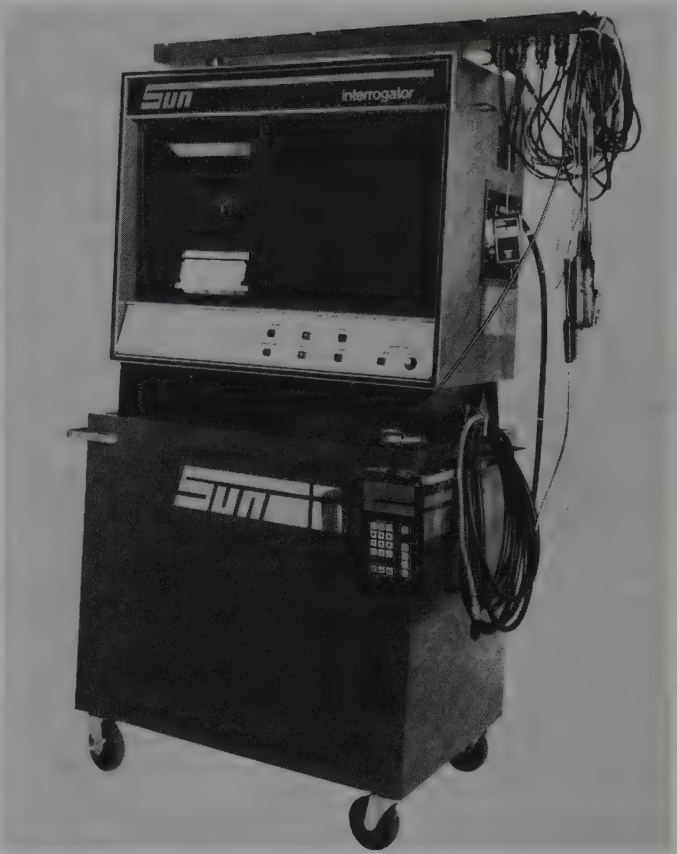


Fig. 24-31. Diagnostic analyzers have the ability to communicate with the electronic control unit and to interpret data from the sensors. This particular model provides the technician with a printout of its findings. (Sun)

Although some systems require specialized testing equipment, many components can be checked using the following traditional test instruments:

1. High impedance multimeter.
2. Tachometer.
3. Vacuum pump and gauge.
4. Timing light.

In the following sections, common methods for testing computer control system components will be covered. Although these tests are not typical for all computer systems, they are designed to provide a general overview of routine testing procedures. Always consult an appropriate owner's manual before attempting to troubleshoot any computer system component.

VISUAL INSPECTION

The first step in pinpointing a computer control system problem is to visually inspect the suspected circuits and all related components. Most computer system problems are caused by loose connections, leaking vacuum hoses, or physical damage. Check electrical terminals for signs of oxidation and misalignment. Wiggling a connector may help locate an open circuit or an area of high resistance. Wiring problems should always be suspected when an open circuit or a faulty sensor is indicated by trouble codes. Check vacuum hoses for cracks and restrictions. Examine hoses for proper connections. Improper hose routing can upset the operation of a computer controlled system.

TESTING CIRCUIT WIRING

Circuit wiring can be checked with a standard ohmmeter. To test a suspected wire, disconnect the wire at both ends of the circuit and measure its resistance with the meter. If the ends of the wire are far apart, the measurement can be taken by attaching one end of the wire to ground. Attach one meter lead to the ungrounded end of the wire and the other lead to a common ground. If the resistance measured in either of these tests is greater than 5 ohms, the wiring should be repaired, Fig. 24-32.

The ohmmeter can also be used to check for a short circuit. Connect the ohmmeter to one end of the wire in question and the other lead to a good ground. If the resistance is less than several hundred thousand ohms, the wire may be shorting to ground.

SENSOR SERVICE

Sensor service usually consists of testing the suspected components and replacing them if they are faulty. An ohmmeter is often required to check the operation of signal-modifying sensors. The meter is used to verify the sensor's internal resistance. A voltmeter is usually used to test the output of signal-producing sensors. All measured values should be compared with service manual specifications. Some systems require a special scan tool to extract voltage and resistance values from the sensors. Never conduct tests on electronic and computerized components without consulting the appropriate service manual. Improper testing methods can destroy a sensor.

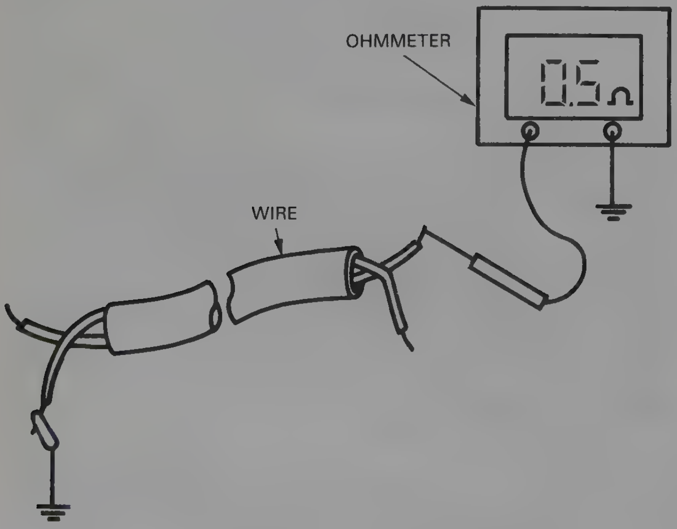


Fig. 24-32. Checking wire condition with an ohmmeter. Make sure wire is disconnected from power source before connecting meter.

OXYGEN SENSOR SERVICE

The oxygen sensor has the ability to produce a small voltage signal, which is used by the electronic control unit to calculate the oxygen content in the exhaust gas. When there is a high oxygen content in the exhaust gas (lean mixture), the oxygen sensor generates a low signal of approximately 0.10 Volt. When the oxygen content is low (rich mixture), the sensor generates approximately 1.0 Volt. Many manufacturers require a scan tool to measure oxygen sensor output. Some oxygen sensors can be checked using a digital voltmeter.

There are two common causes of oxygen sensor failure. The first is age. Under normal operating conditions, an oxygen sensor can be expected to last approximately 70,000 miles. The second and most common cause of oxygen sensor failure is contamination. Carbon, lead, silica, and oil can all contaminate an oxygen sensor. The buildup of these substances will eventually cause sensor failure.

If a vehicle experiences multiple oxygen sensor failures, check for sensor contamination, Fig. 24-33. Carbon leaves a black, fluffy coating. Silica contamination appears in the form of a white powder. Engine oil usually leaves a brown residue on the oxygen sensor. The cause of the contamination should be eliminated before replacing sensor.

NOTE: The oxygen sensor is a very delicate device and should never be tested with an ohmmeter.

ENGINE SPEED SENSOR SERVICE

When operating properly, the engine speed sensor generates a small voltage signal that is proportional to the speed of the engine. If the sensor is faulty, the

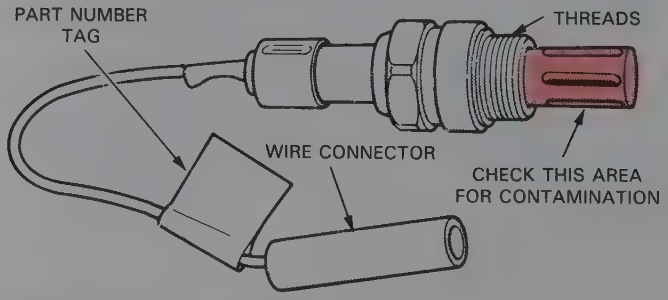


Fig. 24-33. Check oxygen sensor for signs of contamination. Buildup of silica, carbon, lead, or oil can cause failure. (Chrysler)

correct voltage will not be produced. A defective engine speed sensor can cause problems with the ignition system and prevent the engine from running, Fig. 24-34. A voltage check is commonly recommended for the engine speed sensor. As the engine is cranked, a small voltage should be produced in the sensor. If the voltage is not within the manufacturer's specifications, the sensor must be replaced. Many manufacturers recommend checking the resistance of the sensor coil. The resistance should be within specifications.

DETONATION SENSOR SERVICE

The detonation sensor converts abnormal engine vibrations into electrical signals. A faulty detonation sensor can adversely affect engine performance and fuel economy. If a trouble code indicates a problem in the detonation sensor circuit, the sensor can be easily checked with a variable timing light. Connect the timing light as recommended and run the engine at a fast idle. Lightly tap the intake manifold or the engine block near the sensor and watch the ignition timing, Fig. 24-35. If the sensor is working correctly, it should retard the timing to compensate for the knock. The amount of change in timing should be proportional to the strength of the tapping. The maximum amount of timing change should be approximately 10 degrees. As an alternate method, some manufacturers recommend the use of a voltmeter or an ohmmeter to check the sensor. If the sensor does not produce the required readings, it must be replaced.

COOLANT TEMPERATURE SENSOR SERVICE

The coolant temperature sensor varies its internal resistance as the operating temperature of the engine changes. The resistance is usually low when the engine is hot and it climbs as the engine cools. Most manufacturers recommend checking the resistance of the sensor at different engine operating temperatures. If the resistance does not change or is not within recommended specifications, check the wiring for shorts or open circuits before condemning the sensor, Fig. 24-36.

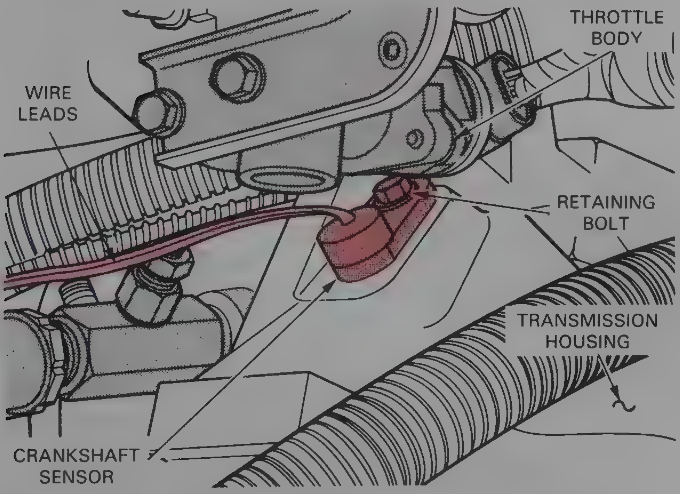


Fig. 24-34. This engine speed sensor mounts directly to block and monitors crankshaft rotation. Make sure retaining bolt is tight and wire leads are intact. (Chrysler)

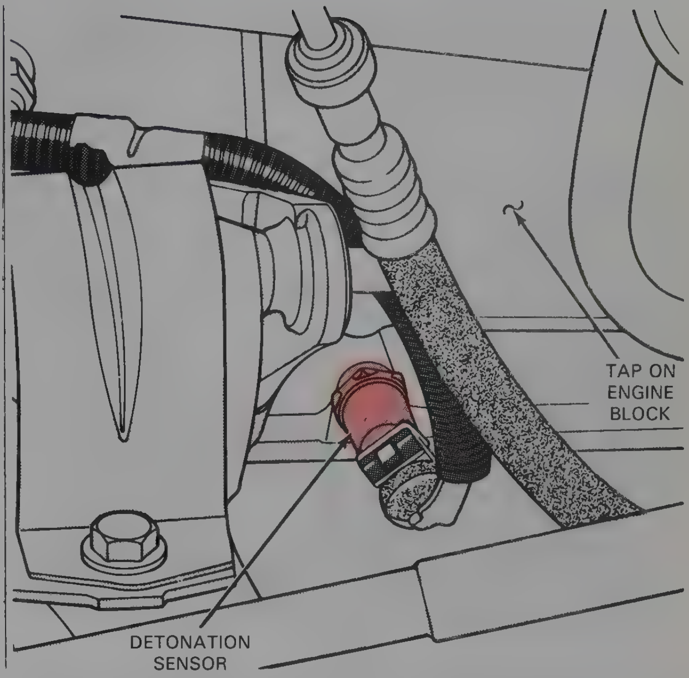


Fig. 24-35. Detonation sensor operation can be checked by observing ignition timing while tapping on engine block. Timing change should be proportional to the strength of the tapping. (Jeep)

MANIFOLD AIR TEMPERATURE SENSOR SERVICE

The manifold air temperature sensor is similar to the coolant temperature sensor. Usually, the resistance of the sensor is checked with a scan tool or an ohmmeter. Always follow manufacturer's instructions when testing. A faulty air temperature can cause an excessively lean or rich fuel mixture.

THROTTLE POSITION SENSOR SERVICE

The throttle position sensor (TPS) changes its output signal in relation to the position of the throttle valve. The signal can range from 0.5 volts at idle to approximately 5 volts at wide open throttle. Many manufacturers recommend checking the TPS with a scan tool. Many of these tools are capable of displaying the signal voltage and the percentage of throttle opening. A voltmeter or an ohmmeter is sometimes recommended to check the operation of the TPS. A common test performed on a TPS involves slowly opening the throttle while monitoring changes in the out-

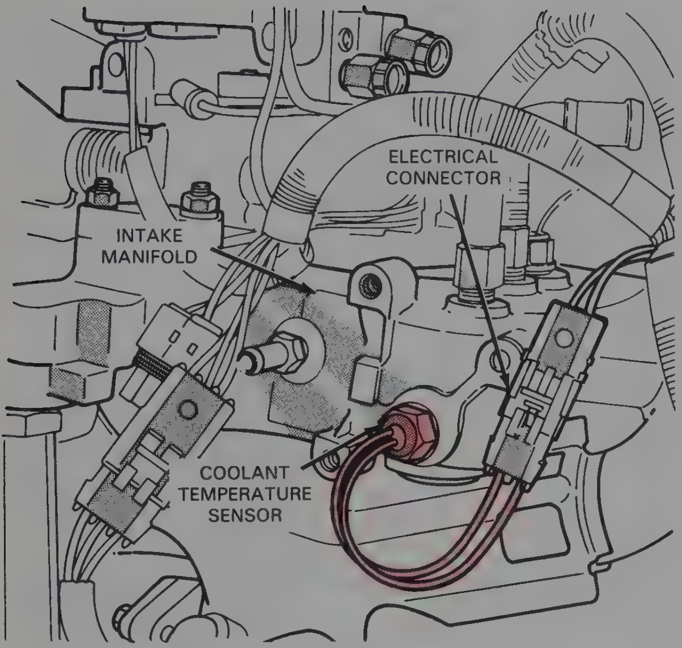


Fig. 24-36. Coolant temperature sensor mounted in intake manifold coolant passage area. Disconnect at electrical connector to check sensor's resistance. (Jeep)

put voltage. The voltage should rise smoothly and continuously in relation to the rate of throttle movement. If the voltage readout is erratic, the TPS must be replaced, Fig. 24-37.

MANIFOLD ABSOLUTE PRESSURE SENSOR SERVICE

The manifold absolute pressure sensor (MAP) responds to changes in manifold pressure (vacuum). An external vacuum source is often required when checking a MAP sensor. The sensor circuit's output voltage is usually checked while applying a specified amount of vacuum to the sensor. If the voltage at the recommended vacuum readings does not agree with the manufacturer's specifications, the sensor must be replaced. Always check vacuum hose connections when a faulty MAP sensor is suspected, Fig. 24-38. Some manufacturers recommend taking resistance readings while applying vacuum to the sensor. A scan tool can also be used to check the manifold absolute pressure sensor. Using the scan tool usually eliminates the need for an external vacuum source. Always follow manufacturer's recommendations when using a scan tool.

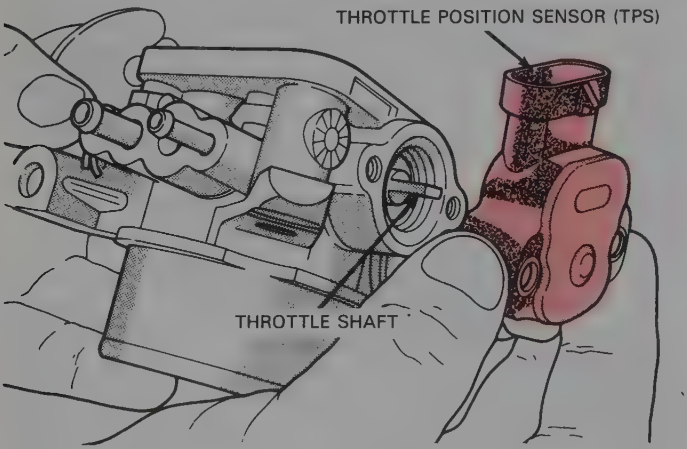


Fig. 24-37. If resistance of throttle position sensor is not within specifications, the unit must be replaced. This sensor was held in place with screws. Some throttle position sensors are equipped with tamper resistant caps that must be removed before sensor can be replaced. (Chrysler)

AIRFLOW SENSOR SERVICE

Most airflow sensors vary their resistance in relation to the amount of air entering the engine. The resistance of some units can be checked with an ohmmeter and compared to the manufacturer's specifications. Some manufacturers recommend checking the sensor circuit output voltage using a digital voltmeter. Always check areas around the sensor for possible air leaks. An air leak around the sensor can cause false readings. Some airflow sensors must be tested with a scan tool. If a flap airflow sensor is used, make sure that the flap is pivoting freely. When checking a mass airflow sensor, make sure that the wire screen is free from obstructions that could restrict airflow, Fig. 24-39.

SWITCHING SENSOR SERVICE

Switching sensors are usually checked with an ohmmeter. If a switching sensor can be manually operated,

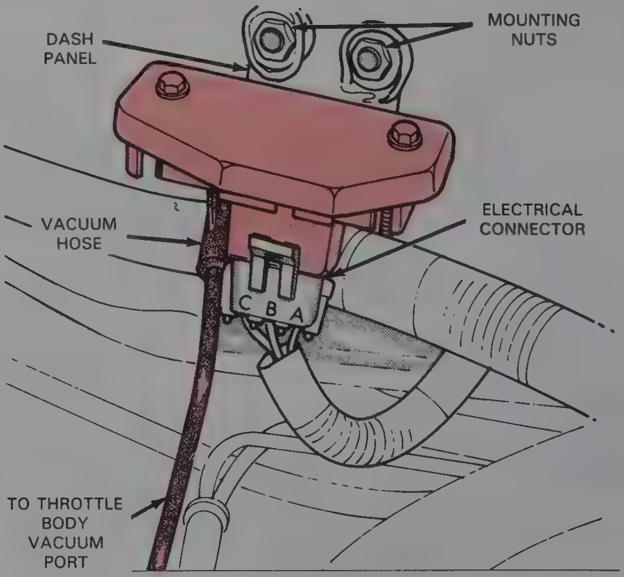


Fig. 24-38. One type of manifold absolute pressure (MAP) sensor. Note vacuum hose that connects sensor to throttle body vacuum port. (Chrysler)

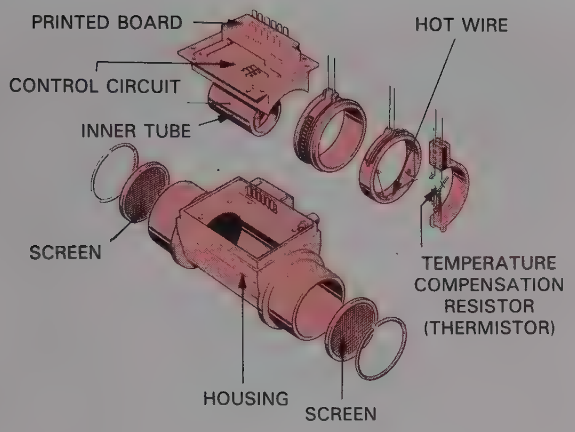


Fig. 24-39. Exploded view of a mass airflow sensor. Check screens for obstructions that could limit airflow. (Bosch)

it should be opened and closed while checking the component's resistance. These sensors should have high resistance when open and no resistance when closed. Switching sensors that use pressure sensitive elements are usually tested by checking resistance readings under specified operating conditions.

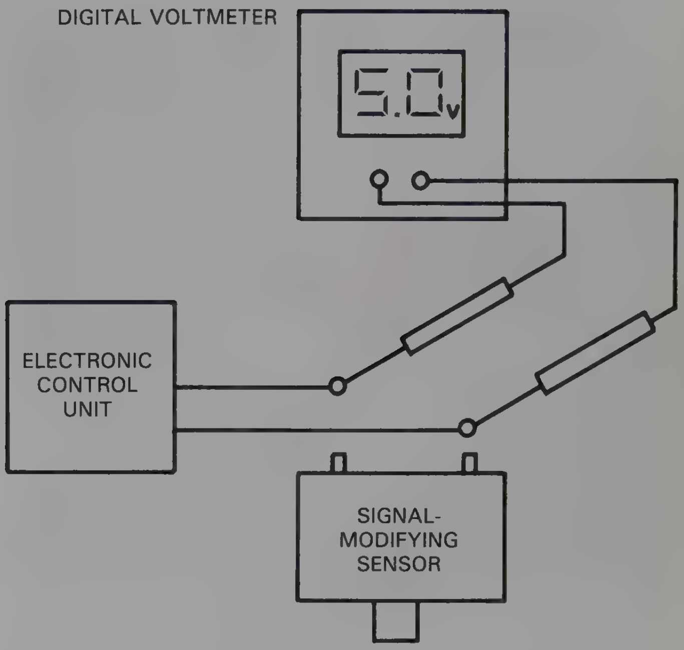


Fig. 24-40. Reference voltage can be checked with a traditional voltmeter. Make sure sensor wiring is in good condition.

CHECKING REFERENCE VOLTAGE

Signal-modifying sensors will not operate properly if they are not receiving an acceptable reference voltage from the electronic control unit. When testing signal-modifying sensors, some manufacturers recommend that the reference voltage be verified.

To check reference voltage, connect a voltmeter to the sensor's input lead, Fig. 24-40. The voltage reading should equal the value recommended by the manufacturer. A low voltage reading can be caused by an area of high resistance, such as an open circuit or a corroded connector. If wiring proves to be adequate, a faulty ECU could be the problem. Always consult the service manual for recommended procedures before attempting to measure the reference voltage.

ACTUATOR SERVICE

Actuators can also cause problems in a computer control system. If an actuator is not operating correctly, the computer cannot control the system properly. Therefore, when a trouble code points to a specific circuit, it is important to verify the operation of the actuators in the circuit. Because actuators are either relays, motors, or solenoids, most actuator tests are fairly standard.

OUTPUT CYCLING TESTS

Some systems with self-diagnostic capabilities have the ability to cycle the computer's output signals on and off. These signals trigger the actuators. Because actuators convert electrical signals into physical movements, most can be seen or heard when cycled on and off.

STANDARD ACTUATOR TESTS

Many systems still require individual actuator tests to verify proper operation. Most units can be checked by measuring their internal resistance with an ohmmeter. If the value measured does not fall within the range specified by the manufacturer, the unit must be replaced, Fig. 24-41.

Some manufacturers recommend using jumper wires to apply an external voltage source (often battery voltage) to the actuator. If the component functions, you can assume that it is working properly.

NOTE: Always follow manufacturer's recommendations when testing actuators. Improper testing methods or excessive voltage can severely damage these units. Always disconnect the actuator from the ECU prior to performing any testing procedures.

ELECTRONIC CONTROL UNIT TROUBLESHOOTING

The electronic control unit is one of the most trouble-free components on today's automobile. Therefore, all other potential trouble spots should be tested before condemning the ECU. Always check the sensors and actuators before attempting to troubleshoot the electronic control unit. Check the wiring to the control unit for

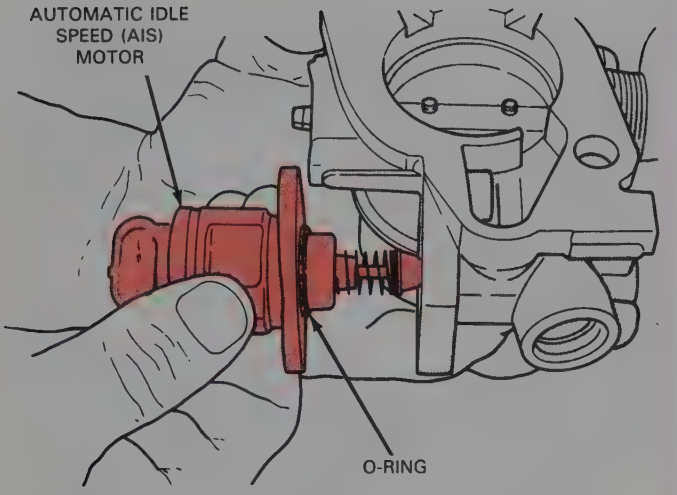


Fig. 24-41. If actuator does not respond when energized, it must be replaced. This idle speed motor is being checked for proper operation. (Chrysler)

shorts and opens. To check for proper connections, unplug and reconnect all connectors going into the ECU.

Most manufacturers require the use of special testing equipment to verify ECU operation. Some units, however, can be tested with ordinary voltmeters and ohmmeters. Some self-diagnostic systems have the ability to locate ECU problems and to place appropriate trouble codes in memory.

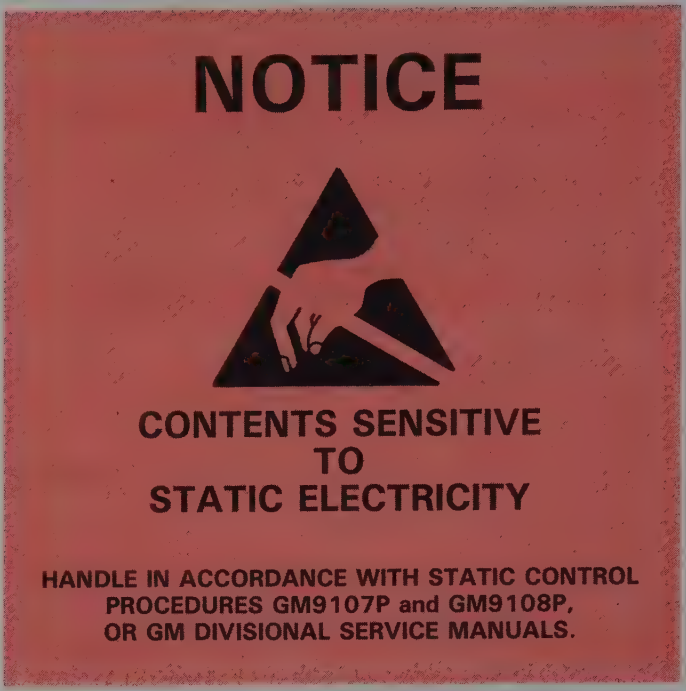
Many technicians still depend on the process of elimination when servicing computer control systems. If all other system components are working properly, they are forced to assume that the electronic control module is causing the problem. This method is not recommended and should only be used as a last resort.

The electronic control module is a very delicate and expensive component. Always follow manufacturer's recommendations when testing and servicing these units.

NOTE: Most electronic control units are sensitive to electrostatic discharge. The static electricity generated by sliding across a seat can destroy an ECU or a PROM chip. To reduce the risk of damage due to static electricity, always touch a good ground before handling the ECU or related electronic components, Fig. 24-42. A grounding strap can also be worn to protect sensitive electronic parts.

SERVICING THE ECU

The electronic control unit, like most sensors, is not serviceable as a unit. When an ECU is found to be defective, it must be replaced. The computer's programmable read only memory chip (PROM), however, is removable and is usually reused when a new electronic control unit is installed. When removing the ECU from a vehicle, always turn the ignition key off. As an added precaution, the battery should be disconnected. The computer can be removed from a vehicle by simply disconnecting all wires from the unit and unbolting it from its mounting brackets.



NOTICE

CONTENTS SENSITIVE
TO
STATIC ELECTRICITY

HANDLE IN ACCORDANCE WITH STATIC CONTROL
PROCEDURES GM9107P and GM9108P,
OR GM DIVISIONAL SERVICE MANUALS.

Fig. 24-42. Always touch a good ground or put on an approved grounding strap before handling components that are sensitive to static electricity. Some units are labeled with a warning similar to the one above. (Pontiac)

When changing an ECU, always replace it with an identical unit. Manufacturers produce many different types of electronic control units. Always record the faulty unit's identification number. The year and model of the vehicle you are working on may not provide the information required to obtain an exact replacement.

MOVING A PROM CHIP

When replacing an electronic control unit, the original PROM chip is often installed in the new unit. This is because the information stored in PROM is very specific to the vehicle being repaired.

A special tool should always be used when handling a PROM chip. Never touch a PROM chip directly. Oil from hands and fingers can have an adverse effect on the operation of the chip. Before removing the chip, note its position. Many manufacturers mark the PROM to ensure proper installation. Gently pull the PROM chip from its socket.

Before installing a PROM into a new unit, make sure it is positioned correctly. If the PROM is installed incorrectly, it will be destroyed, Fig. 24-43.

To install a PROM, simply press it into the correct socket in the ECU. A blunt, nonmetallic object should be used to avoid touching the chip. Gently press on

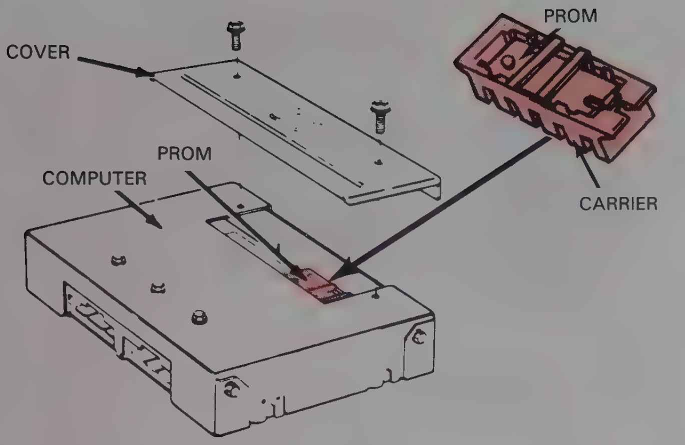


Fig. 24-43. The PROM chip can be moved from one computer to another. Never touch PROM with bare hands. Note that this PROM chip is mounted in a special carrier.

the corners of the PROM to make sure it is seated properly.

BODY COMPUTER SYSTEMS

Up to this point, we have been dealing with typical components used in computerized engine control systems. The remainder of this chapter will deal with body computer systems. A body computer system controls any function that does not affect engine operating conditions. The sensors, control units, and actuators used in body computer systems are similar to those found in computerized engine control systems. Typical body computer systems include:

1. Anti-lock brake systems.
2. Air bag systems.
3. Active suspension systems.

AIR BAG SYSTEMS

Most body computer systems are offered as expensive options. However, an increased interest in occupant safety has prompted manufacturers to include air bag systems as standard equipment on many of their vehicles. These systems are designed to deploy when a vehicle is involved in a frontal collision of reasonable force. Most air bag systems consist of several common components, Fig. 24-44. These components include:

1. Diagnostic control module.
2. Front impact sensors.
3. Coil assembly.
4. Inflator module.

These components work together to fully deploy the air bag within 50 milliseconds of impact. See Fig. 24-45. After deployment, the air bag will deflate in approximately 100 milliseconds.

DIAGNOSTIC CONTROL MODULE

The diagnostic control module performs several functions in the air bag system, Fig. 24-46. The module serves as a monitoring system for the air bag components, warns the driver of system malfunctions by activating the air bag indicator light, and stores trouble codes, which are used during system diagnosis.

If battery voltage is lost in an accident, most diagnostic control modules provide the air bag system with an alternate source of power.

The diagnostic control module also contains a special safing sensor, designed to prevent accidental deployment. This sensor must close simultaneously with one of the impact sensors to trigger the air bag system. The safing sensor prevents a faulty front impact sensor from activating the air bag system, Fig. 24-47.

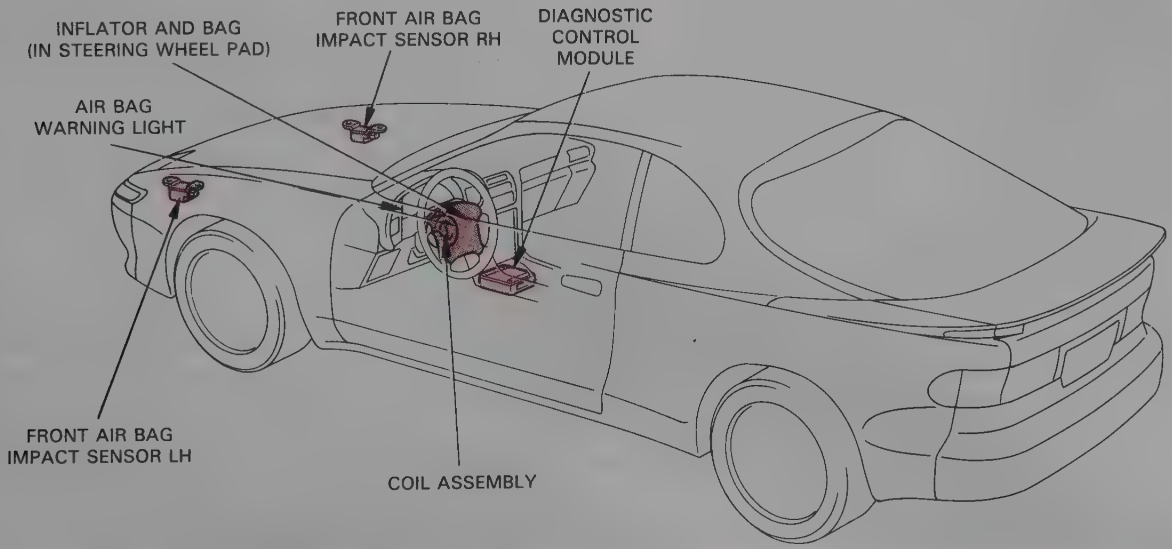


Fig. 24-44. Typical air bag system components. Note location of front impact sensors and inflator module. (Toyota)

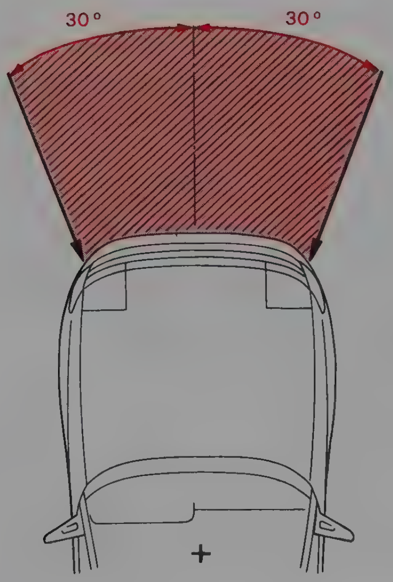


Fig. 24-45. Air bag system will be deployed if vehicle is involved in a frontal collision within 30° of its centerline. (Toyota)

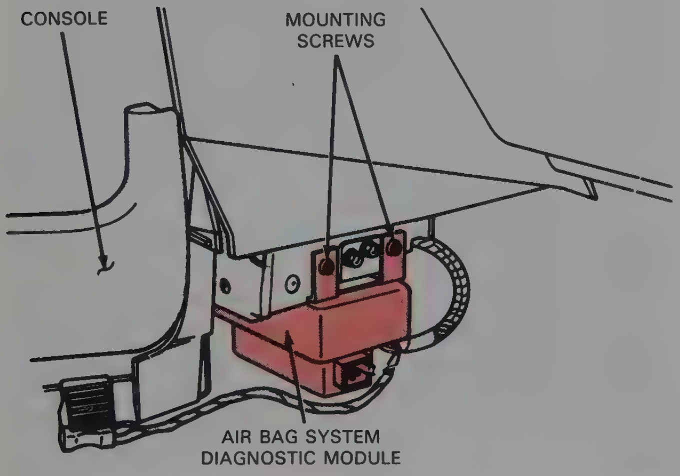

CONSOLE
MOUNTING SCREWS
AIR BAG SYSTEM DIAGNOSTIC MODULE

Fig. 24-46. Typical air bag diagnostic module. Note that this unit is mounted under the dash and near the center console. (Chrysler)

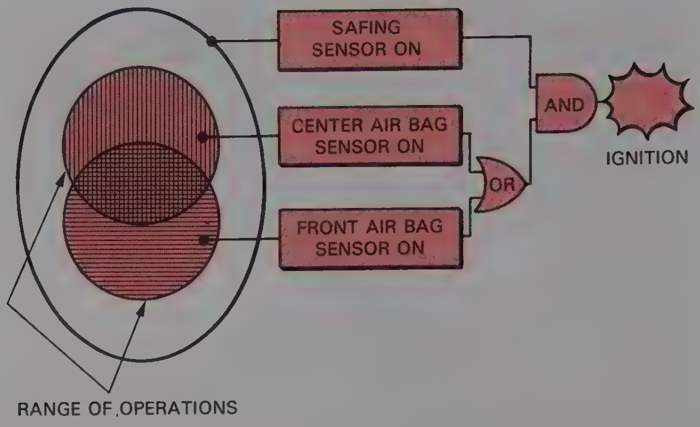
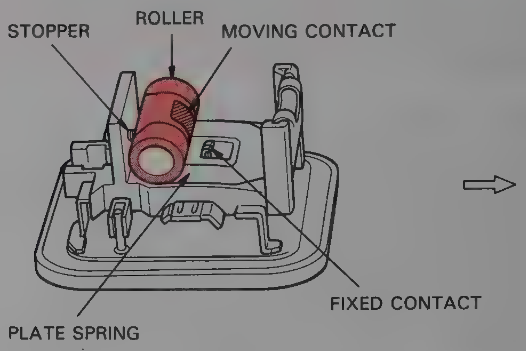
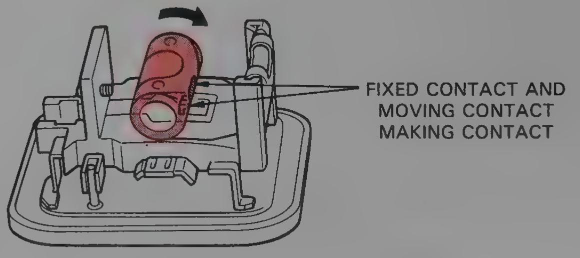

SAFING SENSOR ON
CENTER AIR BAG SENSOR ON
FRONT AIR BAG SENSOR ON
AND
OR
IGNITION
RANGE OF OPERATIONS

Fig. 24-47. To avoid accidental deployment, most air bag systems employ a safing sensor. This sensor must close simultaneously with one front impact sensor to trigger the system. (Toyota)


STOPPER
ROLLER
MOVING CONTACT
FIXED CONTACT
PLATE SPRING

WHEN NOT OPERATING

⇨ DECELERATION


FIXED CONTACT AND MOVING CONTACT MAKING CONTACT

WHEN OPERATING

Fig. 24-48. One type of front impact sensor. If vehicle is involved in a collision, the roller will move forward, closing the switch. (Toyota)

IMPACT SENSORS

The impact sensors are usually located on the front section of a vehicle's frame or on each side of the radiator housing. An impact sensor is an open switch, which is designed to close when an impact provides a velocity change that is severe enough to warrant air bag deployment. Fig. 24-48 illustrates typical impact sensor operation.

COIL ASSEMBLY

The coil assembly consists of two current-carrying coils, which are attached to the vehicle's steering column. As the steering wheel is rotated, these coils maintain a continuous electrical connection between the inflator module and diagnostic module. A typical coil assembly is illustrated in Fig. 24-49.

INFLATOR MODULE

The inflator module is located in the center of the steering wheel in driver's side air bag systems. This module contains the inflatable fabric air bag, an initiator squib,

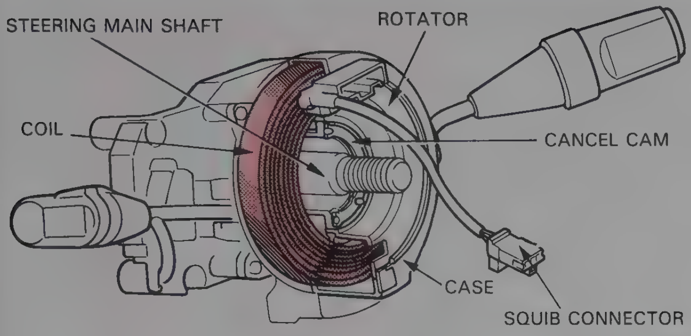

STEERING MAIN SHAFT
ROTATOR
COIL
CANCEL CAM
CASE
SQUIB CONNECTOR

Fig. 24-49. Cutaway view of a typical coil assemply. Note squib connector, which connects coil assembly to inflator module. (Toyota)

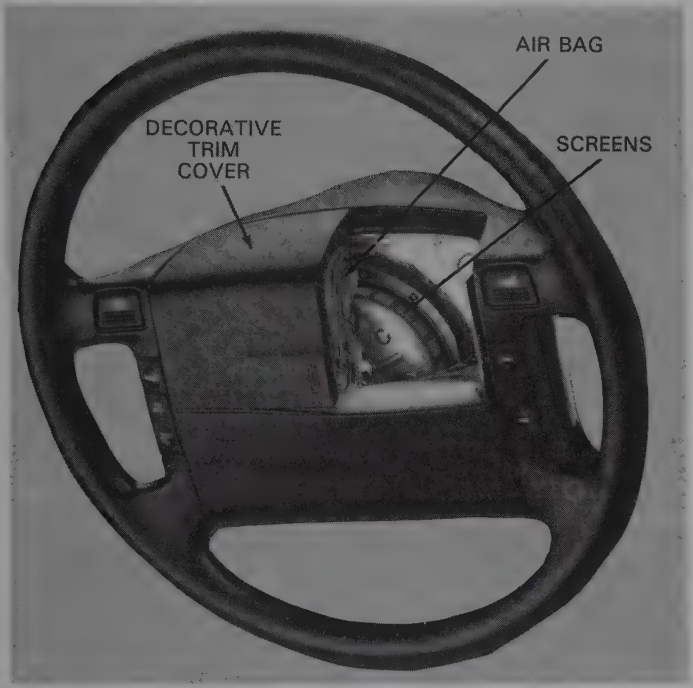

AIR BAG
DECORATIVE TRIM COVER
SCREENS

Fig. 24-50. Cutaway view of an inflator module housed in steering wheel assembly. Note air bag folded under decorative trim. (Ford)

and an inflator (gas generating material). The inflator module is usually covered with a decorative trim piece, Figs. 24-50 and 24-51. In addition to a driver's side air bag, some vehicles are equipped with a passenger side air bag. Passenger side inflator modules are usually mounted above the glove box on the passenger side of the vehicle. An inflator module for a passenger side air bag system is shown in Fig. 24-52.

AIR BAG OPERATION

When a vehicle is involved in a collision that is severe enough to warrant air bag deployment, the impact sensors close. If at least one impact sensor and the safing sensor in the diagnostic module close, a signal is sent to the initiator squib. When signaled, the squib generates a thermal reaction which, in turn, ignites the gas generating material (sodium azide based propellant) in the inflator, Fig. 24-53. This material releases a large amount of harmless gas, which quickly fills the air bag.

TROUBLESHOOTING AIR BAG SYSTEMS

CAUTION: To avoid possible deployment, consult the proper service manual before attempting to

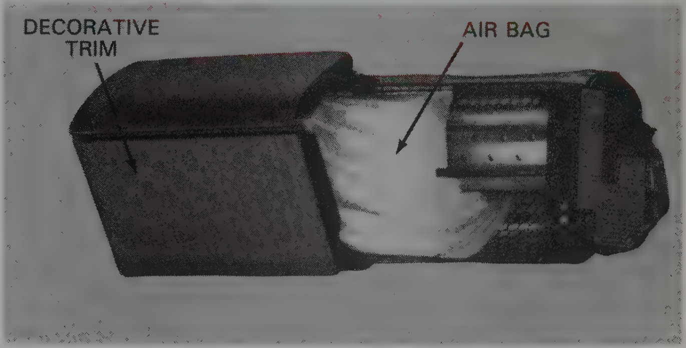

DECORATIVE TRIM
AIR BAG

Fig. 24-52. Cutaway view of a passenger side inflator module. (Ford)

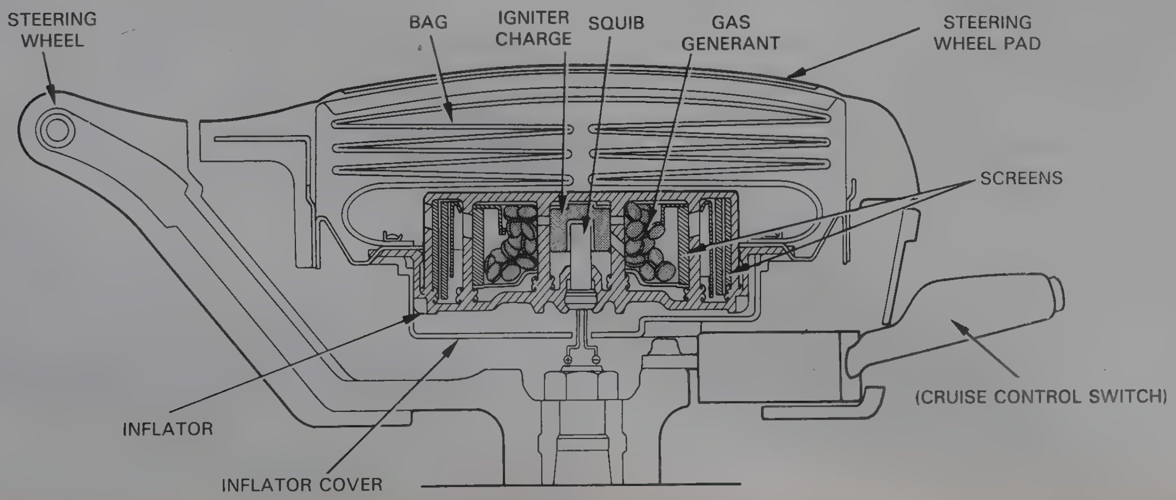

STEERING WHEEL
BAG
IGNITER CHARGE
SQUIB
GAS GENERANT
STEERING WHEEL PAD
SCREENS
(CRUISE CONTROL SWITCH)
INFLATOR
INFLATOR COVER

Fig. 24-51. One type of air bag inflator module. Note screens that allow gas from generant to enter bag. (Toyota)

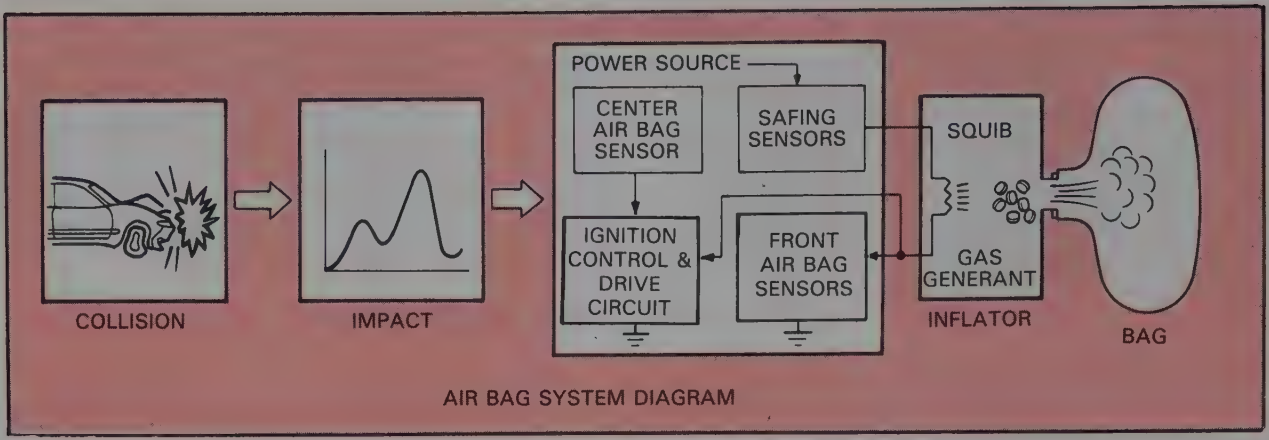


Fig. 24-53. Typical air bag activation sequence. Note that safing sensor and front impact sensor(s) must be triggered to cause deployment. (Toyota)

troubleshoot air bag systems. Most manufacturers require the use of special testing equipment when servicing an air bag system. Using incorrect testing procedures can activate the system.

The self-diagnostic system should be used when troubleshooting air bag systems. Since procedures for accessing trouble codes vary, consult an appropriate manual before attempting to trigger the diagnostic system. Most manufacturers produce a special scan tool to retrieve codes.

Many components in an air bag system are not serviceable. If trouble codes indicate a faulty component, it must be replaced, Fig. 24-54. To prevent accidental deployment, always disable the air bag system before attempting repair procedures. Most manufacturers simply recommend disconnecting battery voltage. Some, however, require the initiator squib to be disconnected. This disables the diagnostic module's alternate power source.

DIAGNOSTIC CODES

CODE NO.	DIAGNOSIS	TROUBLE AREA
11	Short circuit in squib wire harness (to ground) Front air bag sensor turned on at all times Center air bag sensor system turned on at all times	• Wire harness • Front air bag sensor • Wire harness • Center air bag sensor assembly
12	Short circuit in squib wire harness (to +B)	• Wire harness
13	Short in squib circuit	• Squib • Wire harness
14	Open in squib circuit	• Squib • Wire harness
15	Open in front air bag sensor wire harness	• Wire harness
22	Open in air bag warning light system	• Bulb • Wire harness
31	Internal malfunction of center air bag sensor assembly	• Center air bag sensor assembly
41	Malfunction stored in memory	

Fig. 24-54. Trouble code chart for a specific air bag system. Always check diagnostic codes before attempting to service an air bag system. (Toyota)

SERVICING A DEPLOYED AIR BAG SYSTEM

Following air bag deployment, most manufacturers recommend replacement of all related parts. Some, however, only require the replacement of the inflator module and the initiator squib. Always replace all items listed in the service manual. In some systems, reusing sensors and diagnostic modules can cause unprovoked activation of the air bag system.

When an air bag is deployed, the process releases sodium hydroxide powder into the vehicle's interior. The powder can cause irritation of the skin, eyes, nose, and throat. Wear rubber gloves and safety glasses when removing the deployed bag. After the bag has been removed, vacuum the interior thoroughly to remove residual powder. Make sure to vacuum the heater and air conditioner outlets, Fig. 24-55. If residue remains, wipe down the interior surfaces with a damp cloth. Follow manufacturer's recommendations for proper disposal.

AIR BAG SERVICE PRECAUTIONS

When working on air bag systems, there are certain precautions that should be taken to reduce the risk of damage to the system and injury to the passengers. These precautions include the following:

1. Always disable the air bag system before attempting to service any component on or near the system (steering column, dashboard, front of engine compartment).
2. Never subject the inflator module to temperatures

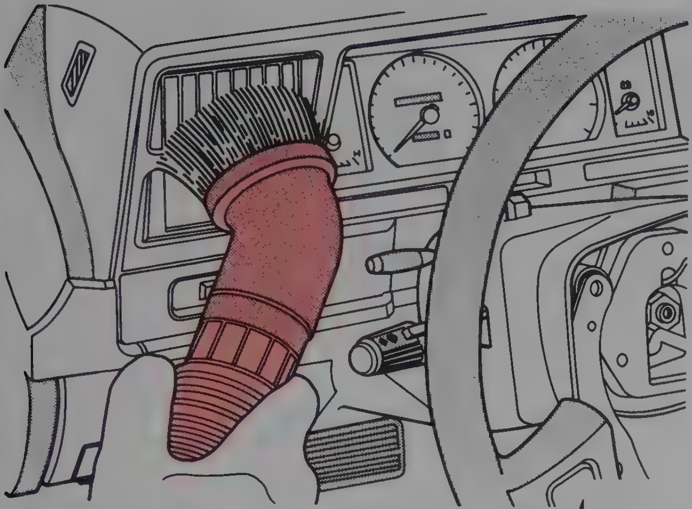


Fig. 24-55. After air bag deployment, vacuum vehicle's interior to eliminate irritating sodium hydroxide powder. (Chrysler)

greater than 175°F (79.4°C).

3. If any part of the air bag system is accidentally dropped, the component should be replaced.
4. Never test air bag components with electrical test equipment unless instructed by manufacturer.

Care should be taken when handling live inflator modules. When carrying a live module, point the bag and trim cover away from you. This will minimize the chance of injury in the case of accidental deployment. When placing a live inflator module on a bench, always face the bag and trim cover up. This will allow the air bag to expand freely in the event of accidental deployment.

ANTI-LOCK BRAKE SYSTEMS

One of the most common body computer systems found on vehicles today is the anti-lock brake system. These systems use electronic and hydraulic components to help prevent wheel lockup during hard braking. Anti-lock brake systems improve occupant safety by maintaining directional control while providing maximum braking efficiency.

ANTI-LOCK BRAKE SYSTEM COMPONENTS

Most anti-lock brake systems contain several common components. These components, shown in Fig. 24-56, include wheel speed sensor units, an anti-lock control module, and a hydraulic actuator.

WHEEL SPEED SENSOR UNITS

Anti-lock brake systems use speed sensor units to determine the rate of wheel rotation. Most wheel speed sensor units consist of a toothed rotor and a sensing unit, Fig. 24-57. The toothed rotor is attached to the vehicle's axle or steering knuckle and rotates at the same speed as the wheel and tire. As the rotor spins, it creates a voltage signal in the sensing unit. The strength and

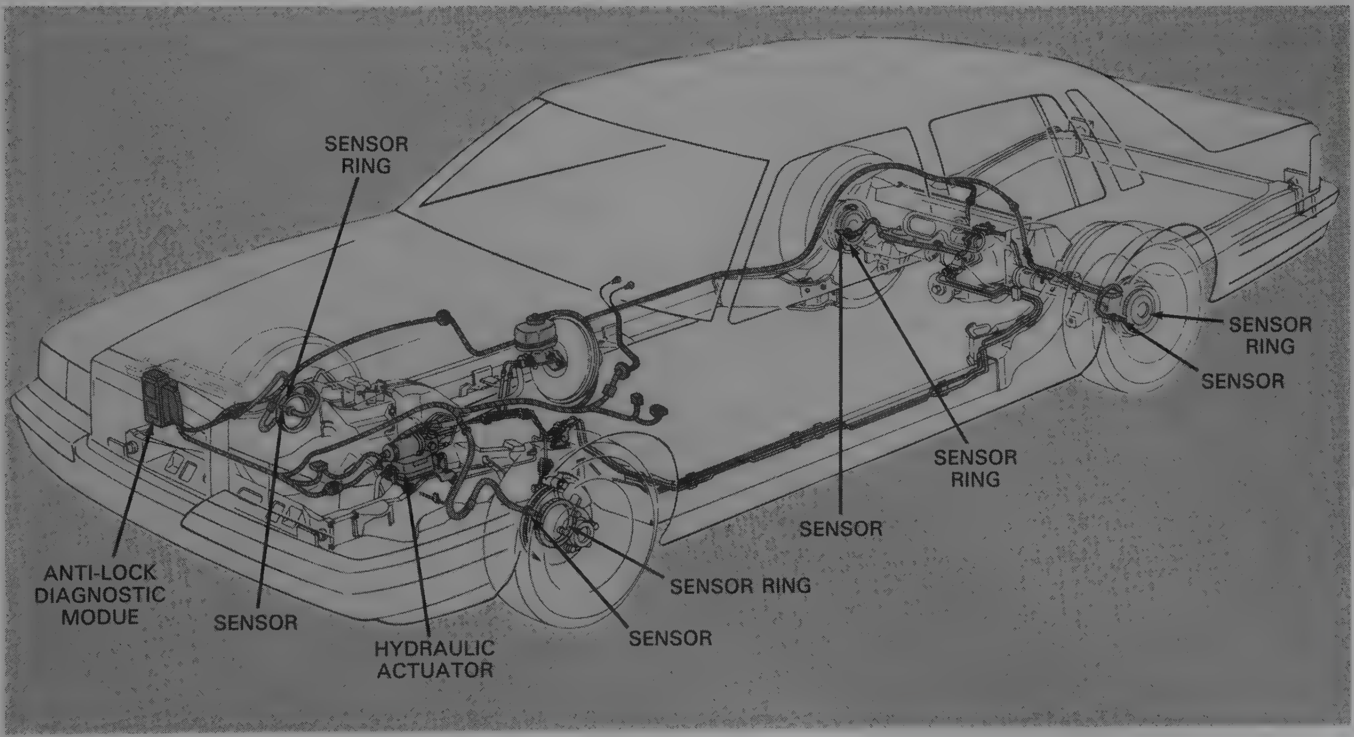


Fig. 24-56. Typical anti-lock brake system. Note speed sensors at each wheel. (Ford)

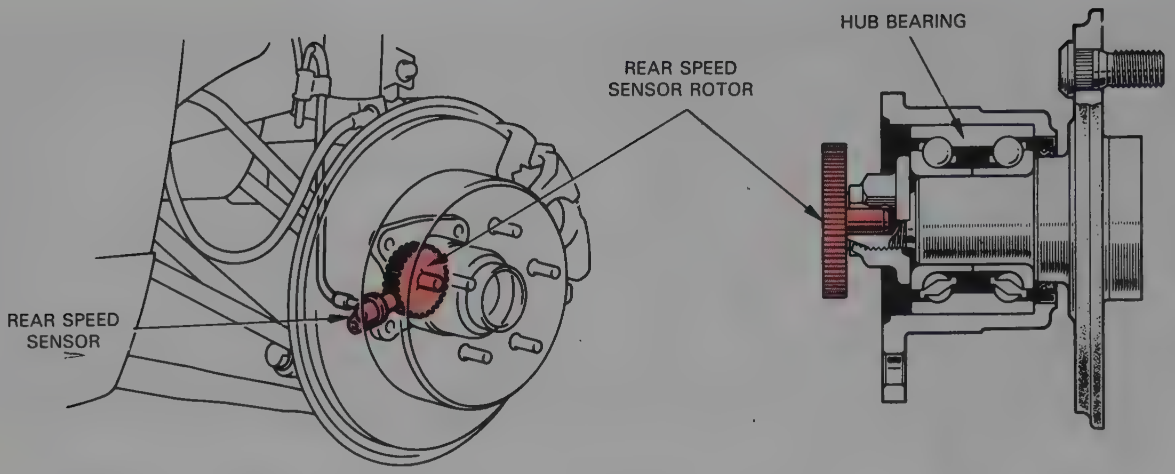

HUB BEARING
REAR SPEED SENSOR ROTOR
REAR SPEED SENSOR

Fig. 24-57. One type of speed sensor located in the vehicle's rear wheel assembly. (Toyota)

frequency of this signal varies in relation to the speed of the wheel.

Some anti-lock brake systems use wheel speed sensing units that are mounted at each wheel. These are called four channel systems. Other systems use speed sensors mounted on the axle housing or in the transmission, Fig. 24-58.

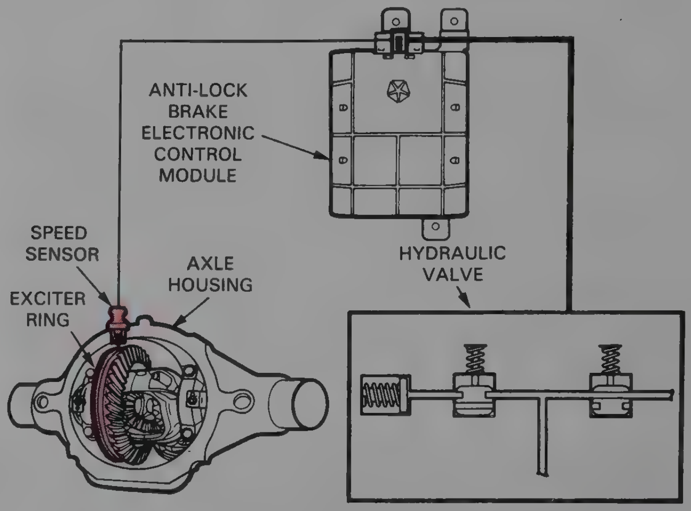

ANTI-LOCK BRAKE ELECTRONIC CONTROL MODULE
SPEED SENSOR
EXCITER RING
AXLE HOUSING
HYDRAULIC VALVE

Fig. 24-58. This particular speed sensor is located in the rear differential housing. (Chrysler)

ANTI-LOCK CONTROL MODULE

The anti-lock control module uses the signals produced by the sensors to determine when the anti-lock system should be activated. When a wheel is nearing a lockup condition, the control module signals the hydraulic actuator to regulate fluid pressure to the wheel.

HYDRAULIC ACTUATOR

The hydraulic actuator is the unit that regulates the pressure delivered to the brakes, based on commands that it receives from the control module. The actuator usually consists of two solenoid valves, a pump, and an accumulator reservoir housed in a single casing.

ANTI-LOCK BRAKE OPERATION

Under normal, light braking conditions, the anti-lock portion of the brake system does not operate. The sensors continuously monitor wheel rotation and send signals to the anti-lock control module. When the brake pedal is pressed, fluid flows from the master cylinder, through the hydraulic actuator, and into the wheel cylinder, Fig. 24-59.

When the control module senses that a wheel is nearing a lockup condition, it signals the solenoid valve in the hydraulic actuator to block the fluid passage between the master cylinder and the wheel cylinder. When

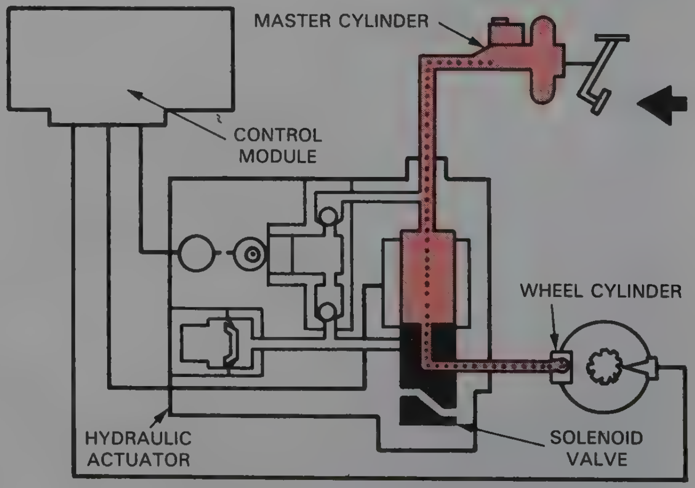

MASTER CYLINDER
CONTROL MODULE
WHEEL CYLINDER
HYDRAULIC ACTUATOR
SOLENOID VALVE

Fig. 24-59. Anti-lock brake system during normal braking. Fluid flows directly through the solenoid into the wheel cylinder.

this occurs, pressure is trapped between the wheel cylinder and the hydraulic actuator. Master cylinder fluid pressure cannot flow through the solenoid valve and the brake pressure at the affected wheel is held constant, Fig. 24-60.

If the control module detects a complete lockup, it will command the hydraulic actuator to decrease pressure to the affected wheel cylinder. To accomplish this, the solenoid valve in the actuator moves to cut off fluid pressure from the master cylinder and to allow brake fluid at the caliper to flow into the accumulator reservoir, Fig. 24-61. At the same time, a pump inside the actuator forces the fluid in the accumulator back into the master cylinder. When this occurs, pressure at the wheel is decreased.

When all the wheels are rotating normally, the solenoid valve in the actuator returns to its original position and the conventional braking system takes over. If necessary, a typical anti-lock system can repeat this cycle up to 15 times a second.

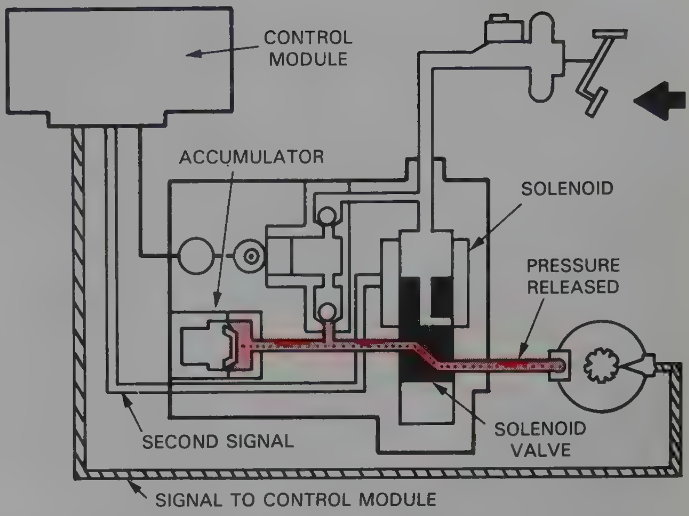


Fig. 24-61. If wheel locks up, the solenoid is instructed to release pressure at the affected wheel. Note fluid flowing back into accumulator.

TROUBLESHOOTING ANTI-LOCK BRAKES

Most anti-lock brake systems have self-diagnostic capabilities. The first step in troubleshooting anti-lock brake systems is to retrieve trouble codes stored in the control module's memory. Many manufacturers require special scan tools to retrieve codes from the anti-lock control module. Always consult the vehicle's service manual for the appropriate method. The trouble codes should be compared to the appropriate trouble code chart to determine potential problems, Fig. 24-62.

Wheel sensors should be inspected for signs of physical damage. A buildup of foreign material between the rotor's teeth can cause the control module to set a trouble code. Many manufacturers recommend checking sensors with an ohmmeter to determine their resistance. If the reading does not fall within specifications, the sensor should be replaced. Always make sure that the wiring from the sensor is routed correctly. Improper wiring can provide false information to the control module and cause a dangerous handling problem when the anti-lock system is activated.

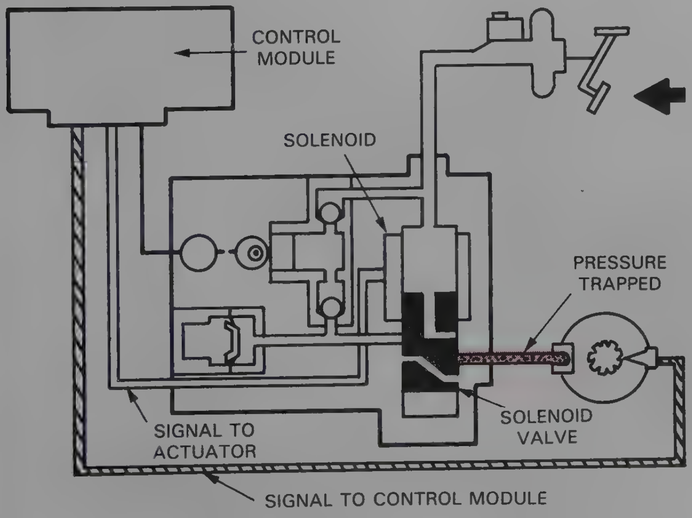


Fig. 24-60. When control unit senses potential lockup, it instructs the solenoid to block fluid flow to the wheel cylinder.

If a faulty hydraulic actuator is suspected, it should be tested according to the manufacturer's recommendations. Manufacturers usually recommend specific ohmmeter tests to determine the condition of the solenoid valves inside of the actuator. Most hydraulic actuators cannot be serviced in the field and, therefore, must be replaced as a unit.

If a trouble code indicates a faulty anti-lock control module, check the input voltage to the unit. If the control module does not receive sufficient voltage, it will not operate properly. Check the wiring to the control module. Make sure all connections are clean and secure. Verify the operation of all related anti-lock system components before condemning the anti-lock control module.

POWERTRAIN CONTROL MODULE

The powertrain control module (PCM) is used to control transmission/transaxle shifting and cruise control operation. To achieve these functions, the PCM often works together with the electronic control unit to control fuel metering and ignition timing.

The powertrain control module, which is generally located under the vehicle's instrument panel, continuously monitors data sent by the various sensors and controls the output circuits of the appropriate systems.

Diagnostic system functions are also controlled by

DIAGNOSTIC CODE (Sensor Check Mode)

Code No.	Diagnosis	Malfunctioning Area
Normal	All speed sensors and sensor rotors are normal	
71	Low output voltage of front right speed sensor	● Front right speed sensor ● Sensor installation
72	Low output voltage of front left speed sensor	● Front left speed sensor ● Sensor installation
73	Low output voltage of rear right speed sensor	● Rear right speed sensor ● Sensor installation
74	Low output voltage of rear left speed sensor	● Rear left speed sensor ● Sensor installation
75	Abnormal fluctuation in output voltage of front right speed sensor	● Front right sensor rotor
76	Abnormal fluctuation in output voltage of front left speed sensor	● Front left sensor rotor
77	Abnormal fluctuation in output voltage of rear right speed sensor	● Rear right sensor rotor
78	Abnormal fluctuation in output voltage of rear left speed sensor	● Rear left sensor rotor

Fig. 24-62. Trouble code chart for a specific anti-lock brake system. Note that this chart only contains code information for the wheel speed sensors. (Toyota)

this unit. If the PCM recognizes an operating problem in the monitored systems, it will alert the driver by triggering the "service engine soon" light. A trouble code will be stored to aid the technician in making proper repairs.

Always follow the manufacturer's recommendations accessing diagnostic codes and servicing the unit.

TRACTION CONTROL SYSTEMS

Some vehicles are now being equipped with traction control systems. These systems govern the engine throttle and the brake system to increase vehicle stability on low-friction or uneven road surfaces, Fig. 24-63. Traction control systems also provide high levels of cornering performance. If the system detects one wheel spinning at a faster rate than the others, it will apply the appropriate amount of braking force to slow the wheel to the correct speed. If the system detects both drive wheels spinning excessively, it has the ability to close the throttle to prevent further spinning. Vehicles equipped with traction control systems usually employ an anti-lock brake system.

TRACTION CONTROL SYSTEM COMPONENTS

Most traction control systems have several common components. Typical systems consist of the following:

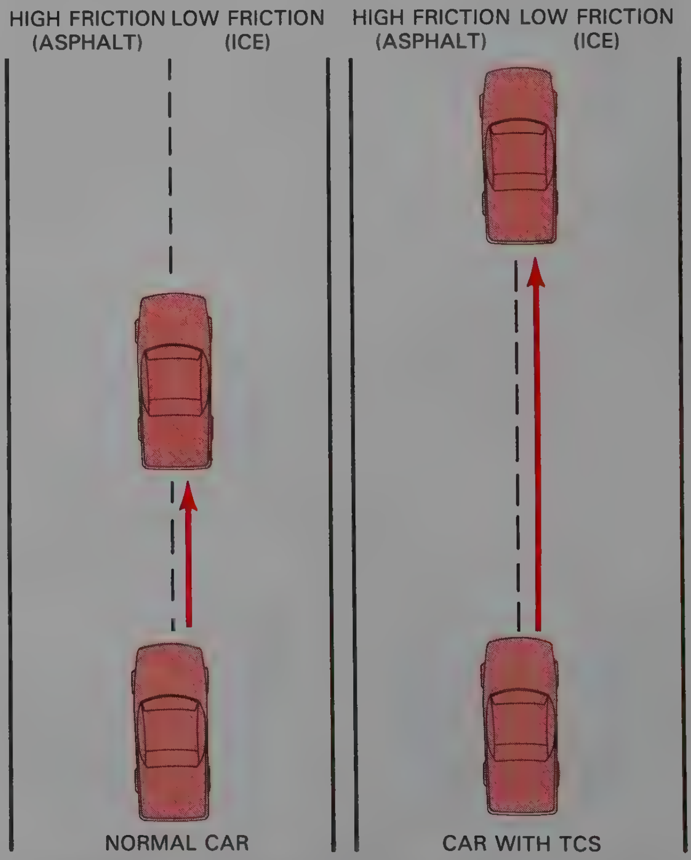


Fig. 24-63. Vehicles equipped with a traction control system accelerate efficiently on low friction surfaces.

1. WHEEL SENSORS (monitor wheel speed and send signals to the control module; usually the same sensors used in anti-lock brake system).
2. CONTROL MODULE (uses signals from sensors to control actuators and throttle motor).
3. THROTTLE MOTOR (moves the throttle plate as instructed by the control module).
4. ACTUATOR (varies the amount of brake pressure at the drive wheels based on signals from control module).
5. INDICATOR LAMP (alerts driver when traction control system is operating).

TROUBLESHOOTING TRACTION CONTROL SYSTEMS

Most traction control systems are equipped with self-diagnostic capabilities. Methods for retrieving trouble codes for these systems vary among manufacturers. Refer to the appropriate service manual for proper diagnostic and service techniques.

COMPUTERIZED RIDE CONTROL SYSTEMS

Computerized ride control systems (active suspensions) are advanced suspension systems, which can adapt to specific driving conditions, Fig. 24-64. Under normal driving conditions, a driver can pick the ride best suited for handling and comfort. For example, if a vehicle is being driven on a winding road, the driver can pick a firm setting. In this mode, the ride control module will signal actuators to close valves on the adjustable shocks. This will produce a stiff ride and the vehicle will corner well. If the vehicle is being driven on a highway, however, the driver can switch to a soft mode. In this setting, the valves in the adjustable shocks are opened and a soft, comfortable ride is produced.

Under certain driving conditions, the control module will override the driver's selection. During periods of hard braking, a brake sensor signals the control module to close the valves on the adjustable front shocks. This stiffens front shocks and minimizes front-end diving. Under heavy acceleration, the acceleration sensor signals the control module to stiffen the adjustable rear shocks, preventing rear-end squatting, Fig. 24-65.

When the driver steers the vehicle into a sharp turn, a steering sensor sends an appropriate signal to the control module. The module signals the actuators to increase shock pressure on the outside of the vehicle. This action decreases vehicle leaning in turns, Fig. 24-66. Other systems, such as sonar, also provide programmed ride control.

COMPUTERIZED RIDE CONTROL SYSTEM COMPONENTS

Typical ride control systems consist of the following components:

1. CONTROL MODULE (uses signals from the steering and brake sensors to control actuators).

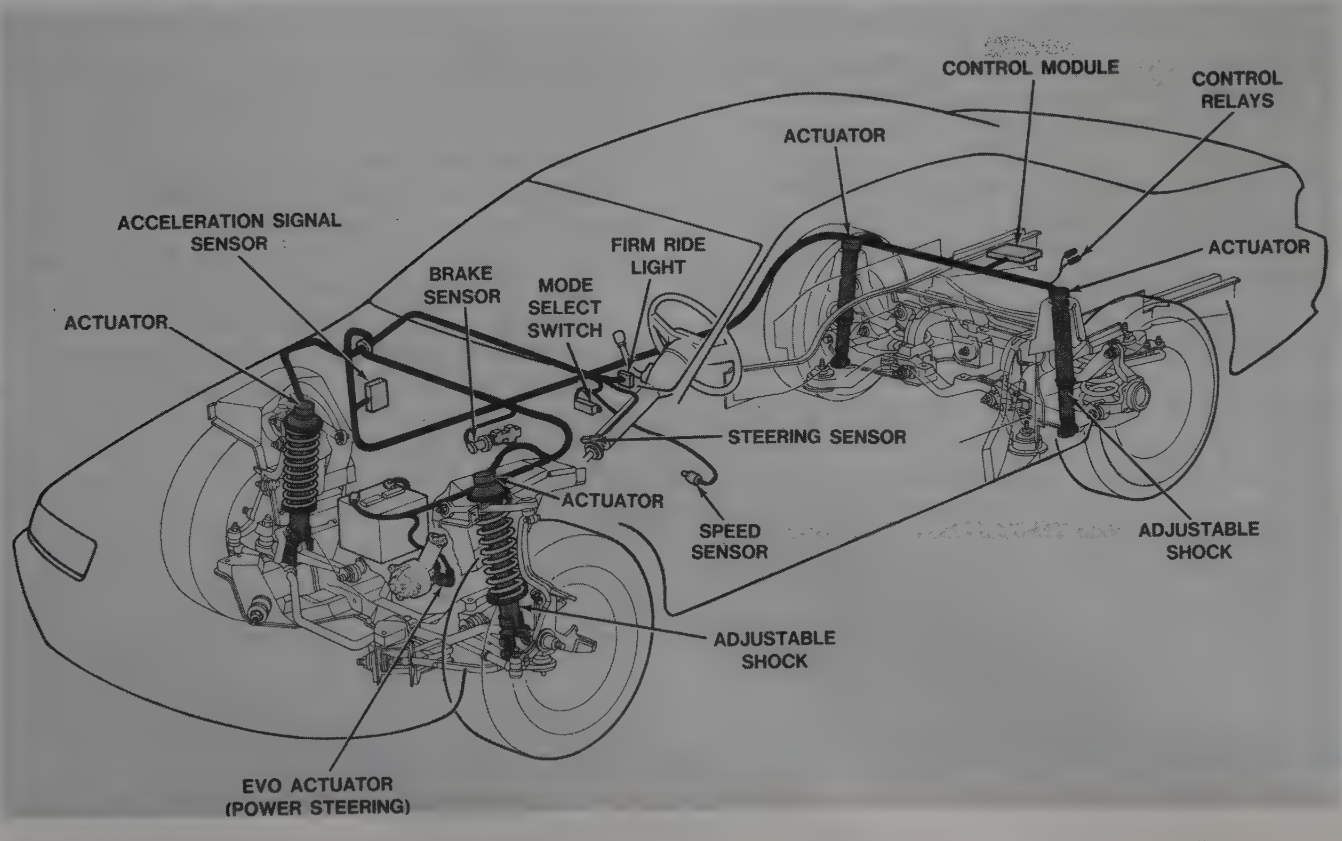


Fig. 24-64. Typical computerized ride control system. Note location of various components. (Ford)

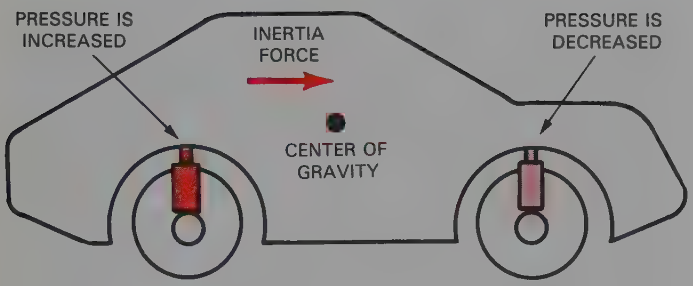


Fig. 24-65. Computerized ride control systems minimize front-end diving and rear-end squatting by stiffening shocks at the appropriate wheels.

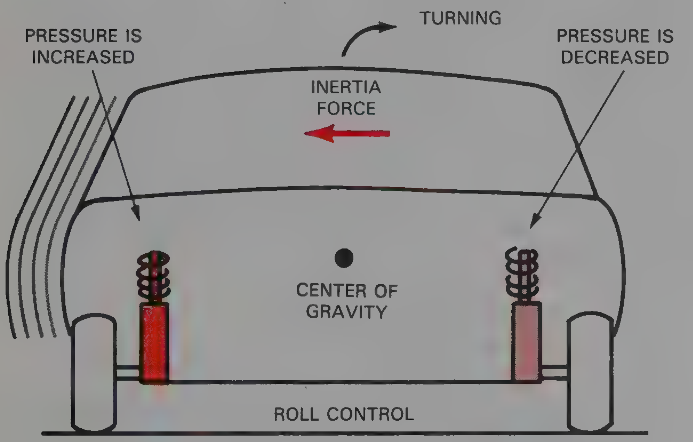


Fig. 24-66. Computerized ride control systems moderate vehicle leaning in turns. Note that shock pressure is increased on the outside of the vehicle.

2. STEERING SENSOR (monitors the direction and speed of steering wheel rotation).
3. BRAKE SENSOR (monitors brake system applications).
4. ACCELERATION SIGNAL SENSOR (monitors rate of acceleration).
5. MODE SELECT SWITCH (allows driver to adjust ride control system).
6. ACTUATORS (control the flow of hydraulic fluid in the adjustable shock absorbers).

RIDE CONTROL SYSTEM TROUBLESHOOTING

Troubleshooting procedures for ride control systems vary among manufacturers. Consult the appropriate service manual for proper instructions. Most ride control systems have self-diagnostic capabilities, which simplify the troubleshooting process.

SUMMARY

Computerized engine control systems offer accurate and instantaneous control over the fuel, ignition, and emission systems. These systems are much more dependable than their mechanical predecessors.

There are several common components in all computer control systems, including sensors, an electronic control unit, and actuators.

Computer control system operation can be divided into three stages. These stages include the input stage, the processing stage, and the output stage. During the input stage, sensors send signals to the electronic control unit. During the processing stage, the ECU analyzes these signals and decides if any adjustments are required. If necessary, engine operating conditions are adjusted during the output stage.

Sensors are devices that convert physical conditions into electrical signals. Some sensors generate their own voltage signal. Other sensors modify a reference voltage that is supplied by the electronic control unit.

The electronic control unit is a complex device constructed of integrated circuits, printed circuit boards, and miscellaneous other electronic components. It is not necessary to know how these components work. However, it is helpful to understand the basic operations of the ECU when trying to locate trouble in computer controlled systems. The ECU can be divided into five sections: the input section, memory section, arithmetic/logic section, control section, and the output section.

Actuators are devices that convert electrical output signals into physical movements. Most actuators can be classified as motors, solenoids, or relays.

A logical approach must be taken when troubleshooting a computer controlled system. Today's automotive technician must rely on information found in service manuals, diagnostic charts, and other service publications when trying to locate problems.

Most computer control systems have self-diagnostic capabilities. These systems continuously monitor the operation of the sensors, the ECU, and the actuators. A trouble code is placed in the computer's memory if an abnormal operating condition is detected. Trouble codes can be accessed in several ways. Always consult the appropriate service manual for the proper method.

Although self-diagnostic systems can locate a malfunctioning circuit, they do not pinpoint the source of the problem. Therefore, specific tests, called pinpoint tests, are often required to locate the exact cause of a problem.

Sensors and actuators can usually be tested with standard equipment. Some manufacturers, however, require the use of specialized diagnostic tools to troubleshoot individual components. Never conduct tests on electronic or computerized components without consulting the appropriate service manual.

A body computer system can be defined as a computer system that controls any function that does not affect engine operating conditions. Typical body computer systems include anti-lock brake systems, air bag systems, and computerized ride control systems. Most body computer systems have self-diagnostic capabilities. Service procedures will vary among manufacturers. Consult the appropriate service manual before attempting to service body computer systems.

Special precautions should be taken when working on vehicles equipped with an air bag system. To reduce the risk of injury, always disable the system before working on or near any air bag system components.

Many vehicles are equipped with powertrain control modules. These units control transmission/transaxle shifting and cruise control operation.

Traction control systems govern the engine throttle and brake system to increase vehicle stability on low friction road surfaces.

Computerized ride control systems can adapt to specific driving conditions and provide a ride best suited for handling and comfort.

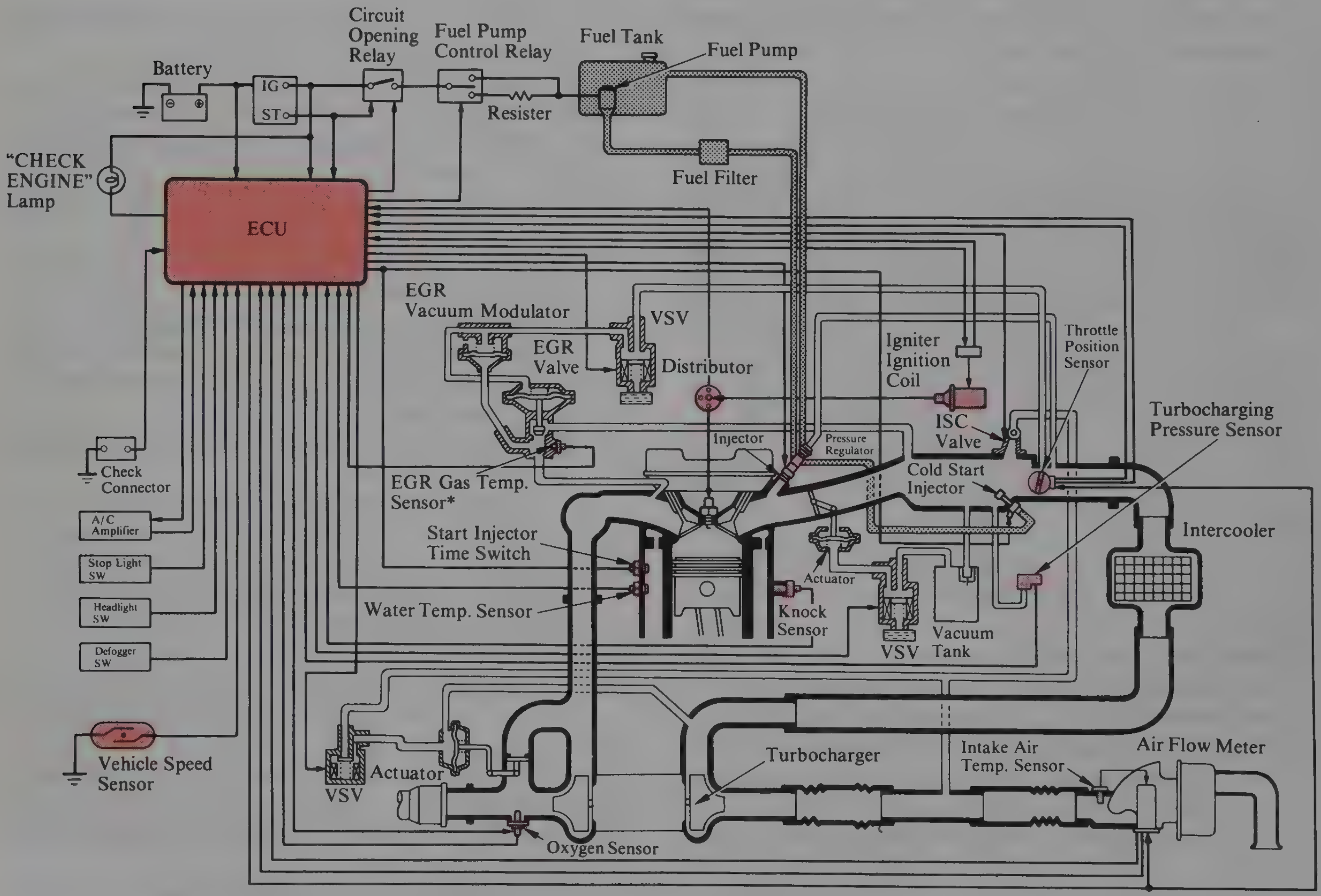
KNOW THESE TERMS

Input stage, Processing stage, Output stage, Signal-producing sensors, Loop operation, Signal-modifying sensors, Reference voltage, Electronic control unit, Memory, ROM, RAM, PROM, Actuators, Troubleshooting, Self diagnosis, Trouble codes, Diagnostic link, Scan tool, Diagnostic analyzer, Pinpoint tests, Body computer systems, Air bag, Diagnostic control module, Impact sensors, Inflator module, Sodium hydroxide powder, Anti-lock brakes, Wheel speed sensors, Control module, Hydraulic actuator, Powertrain control module (PCM), Traction control system, Ride control system.

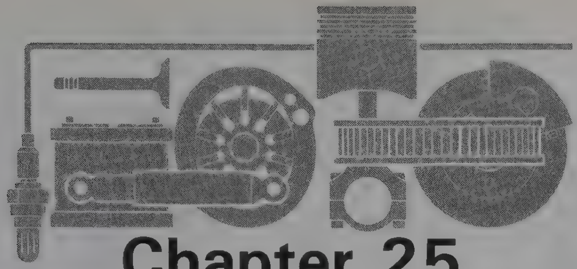
QUIZ - Chapter 24

1. The use of computers in the automotive industry was prompted by governmental regulations requiring better ____________ and fewer ____________.
2. The three components common to most computer control systems are Sensor, Cont, and In[illegible].
3. The three stages of computer system operation include the input, proces, and out put.
4. Explain computer loop operation. Oxigen sensor used
5. A sensor is a device that converts a physical condition into an electrical signal.
6. A sensor that generates its own voltage signal is called a voltage-generator.
7. An oxygen sensor monitors the oxygen content in the exhaus Manifol.
8. A sensor that alters a reference voltage is called a potentiometer Resisor.
9. A mass airflow sensor eliminates the need for a barometric pressure sensor. [✓ True] or False?
10. The three types of memory commonly used in an automotive computer system include Rom, [illegible], and Ram.
11. Actuators convert electrical signals into mechanical signal.
12. To assist the technician when troubleshooting computer controlled systems, many manufacturers have designed onboard-compute capabilities into their systems.
13. If a problem occurs in a computer controlled system, the self-diagnostic system responds by:
    a. Forcing engine into closed loop operation.
    [✓ b.] Placing a trouble code into the systems memory.
    c. Sending reference voltage to the affected circuit.
    d. All of the above.
14. The Diagnostic connector is used as a connecting point for various test equipment.
15. A flashing warning light is often used to display trouble codes. [✓ True] or False?
16. Circuit wiring can be tested for short and open circuits by using a(n) ohmmeter.
17. An oxygen sensor should never be tested with an ohmmeter. True or [✓ False?]
18. Since most actuators can be classified as motors, relays, or solenoids, they can be tested by applying an external voltage to the appropriate input terminals.
19. Output cycling tests perform the following operation:
    a. Measure the output of various sensors.
    b. Verify the operation of the self-diagnostic system.
    [✓ c.] Switch ECU output signals on and off to verify operation of actuators.
    d. All of the above.
20. The last component to be tested in the computer control system should be the computer itself ____________.
21. If the electronic control unit is faulty, it must be replaced. [✓ True] or False?
22. The only part of the electronic control unit that can be serviced is:
    a. The internal printed circuit board.
    b. The arithmetic/logic section.
    [✓ c.] The PROM chip.
    d. All of the above.
23. Body computer systems control the ignition timing and the air-fuel ratio. True or [✓ False?]
24. Air bag systems deploy in the event of a [illegible] collision.
25. The impact sensors in an air bag system are located on the vehicle's fire wall. True or False?
26. Always ____________ the air bag system before attempting to service any component on or near the system's components.

27. The best way to check air bag system components is to use a powered test light. True or False?
28. When handling a live inflator module, always point the bag and trim cover ____________.
29. Most anti-lock brake systems have self-diagnostic capabilities. True or False?
30. Most components on an anti-lock brake system cannot be serviced in the field and must be replaced if they are faulty. True or False?
31. The powertrain control module controls transmission/transaxle shifting and cruise control. True or False?
32. Powertrain control module operation is coordinated with the operation of the ____________ ____________ ____________ to govern fuel metering and ignition timing.
33. Traction control systems control the ____________ system and the engine ____________.
34. The wheel sensors in a traction control system are similar to those used in an anti-lock brake system. True or False?
35. Computerized ride control systems can minimize front-end ______________ during periods of hard braking.


Circuit Opening Relay
Fuel Pump Control Relay
Fuel Tank
Fuel Pump
Battery
IG
ST
Resister
"CHECK ENGINE" Lamp
Fuel Filter
ECU
EGR Vacuum Modulator
VSV
EGR Valve
Distributor
Igniter Ignition Coil
Throttle Position Sensor
ISC Valve
Turbocharging Pressure Sensor
Injector
Pressure Regulator
Cold Start Injector
Check Connector
EGR Gas Temp. Sensor*
Intercooler
A/C Amplifier
Start Injector Time Switch
Actuator
Stop Light SW
Knock Sensor
Water Temp. Sensor
Headlight SW
VSV
Vacuum Tank
Defogger SW
Vehicle Speed Sensor
Turbocharger
Intake Air Temp. Sensor
Air Flow Meter
Actuator
VSV
Oxygen Sensor

Study the components of this computerized engine control system carefully. Today's automotive technician must be familiar with the operation of these systems to effectively service modern vehicles. (Toyota)



Chapter 25

TUNE-UP, ENGINE SYSTEMS, PROBLEM DIAGNOSIS

After studying this chapter, you will be able to:

☐ Explain the term "tune-up."
☐ List the basic steps for a complete tune-up.
☐ Perform a compression test.
☐ Complete a cylinder balance test.
☐ Perform a vacuum test.
☐ Use a cylinder leakage detector.
☐ Summarize important preliminary tests.
☐ Do road and dynomometer tests.
☐ Explain engine system problem diagnosis.

WHAT IS A TUNE-UP?

As commonly practiced in automotive service, a tune-up can be described as THE PERIODIC PROCESS OF INSPECTING, TESTING, ADJUSTING, CLEANING, REPAIRING, OR REPLACING CERTAIN COMPONENTS TO RESTORE ENGINE PERFORMANCE, (horsepower, torque, mileage, smoothness of operation, emission levels) TO THAT NORMALLY EXPECTED FROM AN ENGINE IN FIRST CLASS CONDITION. A tune-up does not entail engine overhaul.

How often a tune-up should be performed, depends on many factors. Engine design, type of fuel, type of service, age of vehicle, and manufacturer's recommendations should all be considered in working out a tune-up time/mileage schedule.

WHAT IS COVERED BY A TUNE-UP?

There is common agreement as to the purpose of a tune-up. However, there is a wide variation in what components are to be covered and to what extent.

One shop may advertise a TUNE-UP for one price while another charges double that amount. What is often overlooked by the customer is that the shop asking the most may be performing a much more comprehensive tune-up.

Some shops offer both BASIC and COMPLETE (sometimes referred to as MINOR and MAJOR) tune-ups. Whatever the coverage, it is important that the shop spells out to the customer exactly what service is to be provided.

COMPLETE COVERAGE IS DESIRABLE

A basic tune-up will probably include a compression test, point and condenser replacement where applicable, checking dwell, timing, distributor advance, carburetor idle mixture and speed settings, and emission levels. Although the tune-up may improve engine performance, the extent of the improvement is influenced by a number of other factors.

For example, why set the idle mixture if the fuel pump pressure is excessive and causes carburetor flooding? Why replace a battery if the alternator regulator is allowing excessive voltage buildup? The new battery will soon be damaged. Why replace spark plugs if the ignition coil output is so low that new plugs will not fire properly? Why carefully set the point dwell when a distributor shaft bushing is worn so that dwell will be highly erratic?

Many shops will not accept BASIC tune-up jobs. They have learned that if they do, and if areas not covered upset engine operation, the customer may be dissatisfied. They may go to another shop, pay for a COMPLETE tune-up, and then blame the first shop.

If the request for a BASIC tune-up is accepted, the limitations of such a job should be explained to the customer. Then, in the event additional work is required, there will be no misunderstanding.

COMPREHENSIVE TUNE-UP

This chapter will cover the procedures for a comprehensive tune-up. Since a successful tune-up is DEPENDENT ON HIGHLY ACCURATE MEASUREMENTS AND ADJUSTMENTS, the equipment used must be of quality construction. The

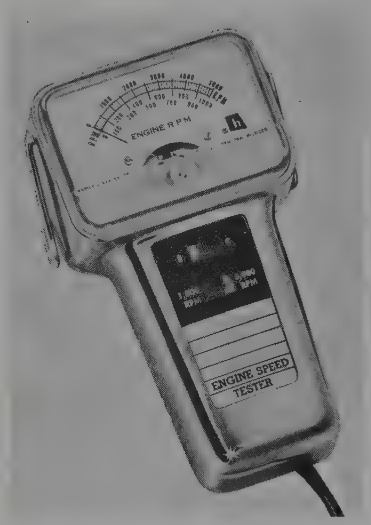


Fig. 25-1. Hand-held tachometer.

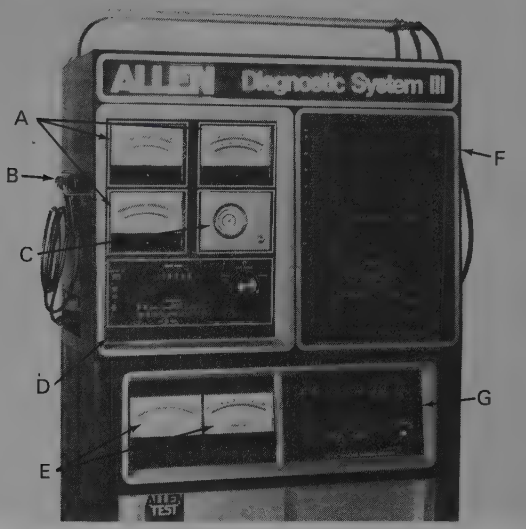


Fig. 25-2. A number of instruments are in this diagnostic test cabinet. This makes for accurate, fast work. A—Test gauges. B—Timing light. C—Vacuum gauge. D—Control panel for gauges. E—Emission gauges. F—Oscilloscope. G—Control panel for emission gauges. (Allen)

equipment should receive periodic checks to assure continued accuracy.

In using the equipment, follow the manufacturer's instructions. Handle the equipment properly and do not subject it to abuse.

Remember that a quality tune-up requires accurate equipment. Test equipment needed for a tune-up typically includes: a voltmeter, ammeter, ohmmeter, dwell meter, oscilloscope, distributor tester, combustion analyzer (emission levels), cylinder leakage tester, compression gauge, fuel pressure gauge, timing light, tachometer, condenser tester, vacuum gauge, spring scale reading in ounces, wire gauge, and feeler gauge.

Instruments may be the individual type, hand held as in Fig. 25-1; or a number may be combined in one cabinet. See Fig. 25-2. Many shops use computerized diagnostic machines to analyze engine systems and

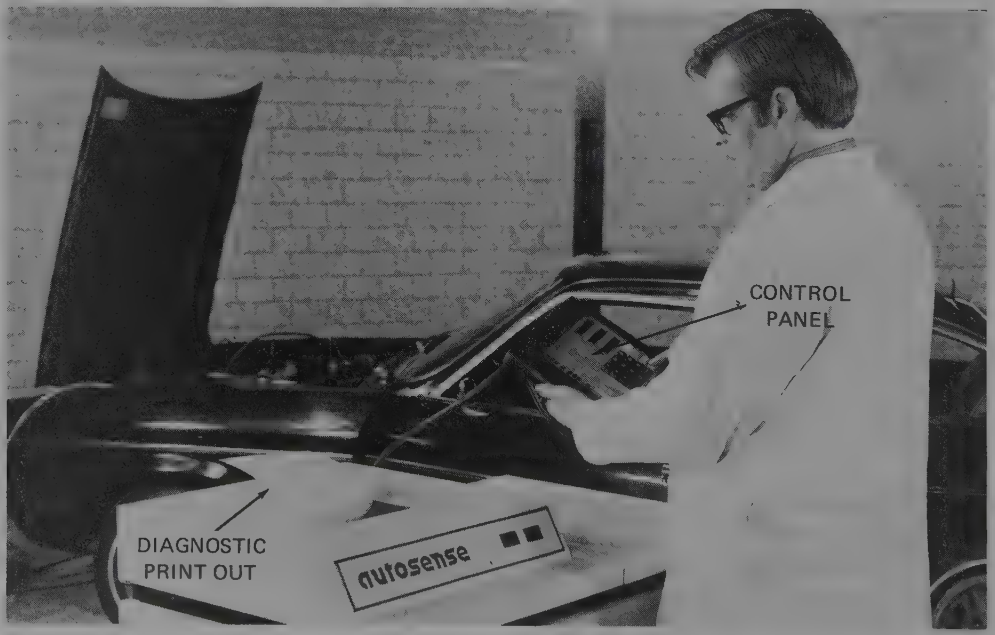


Fig. 25-3. Mechanic using a computerized diagnostic unit. Unit is programmed for car at hand by means of tape cassette. It tests and provides a printout on various areas such as plugs, compression, ignition (primary and secondary), starter, battery, and emissions. (Autosense)

reveal problem areas via a "printout." See Fig. 25-3. Many cars have diagnostic plug-in connections for the fuel injection, air conditioning, and other systems. Fig. 25-4 shows one type of tester being connected to the engine compartment diagnostic plug.

When used with recommended equipment, diagnostic procedures are greatly simplified.

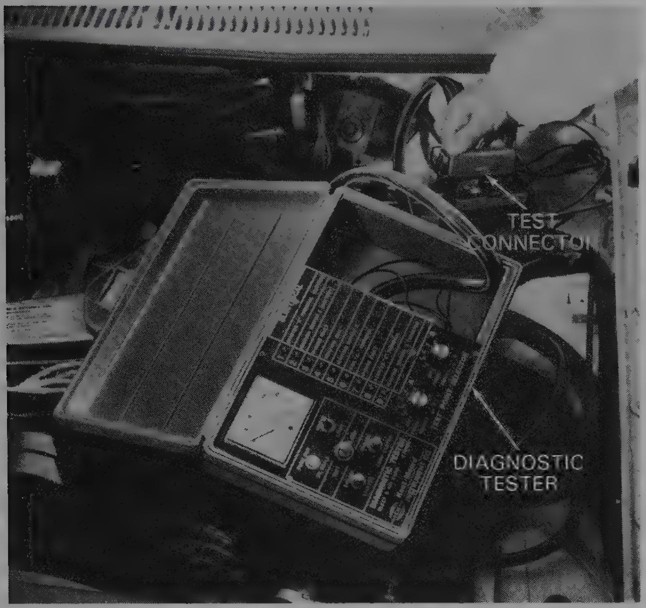


Fig. 25-4. One form of specialized diagnostic test tool designed to be plugged into the car's built-in test connector. Follow directions carefully! (Kent-Moore)

SPECIFICATIONS AND QUALITY PARTS

Tune-up specifications (plug gap, idle speed, timing, etc.) must apply to the EXACT ENGINE and year model being tuned. Even though the engine may remain basically unchanged for years, there may be minor changes that affect specifications.

When replacement is required, use top quality parts that will fit properly, function correctly, and provide adequate service life.

SOLICIT OWNER COMMENTS

Before starting a tune-up, ask the owner for any comments regarding engine starting or performance.

Try to relate any comments to a definite CONDITION (hard starting, poor acceleration, missing); SPEED (slow, medium, or high); GEAR (low, second, high, neutral); ENGINE TEMPERATURE (cold or hot); WEATHER CONDITIONS (cold, hot, wet, dry); FREQUENCY (once in awhile, all the time); CHANGE (work done on car, new parts installed, using a different fuel); SOUND (spitting, howl, grind, whistle).

A set of prepared questions may be used to make sure all important areas are discussed.

The owner's comments and answers to specific questions will provide valuable clues that will assist in uncovering trouble spots.

KEEP SERVICE RECORDS

On all service jobs, keep an accurate record of all parts repaired or replaced, and the date and mileage at the time of installation. These records will be helpful in diagnosing trouble at some future date. The life span of many parts may be fairly accurately gauged in time, or in miles. An accurate record is, of course, essential in handling guarantee work and for service billing.

USE SERVICE RECORDS

If the customer is a "regular," check the service records for length of time or mileage since the last tune-up. Note the mileage since tune-up parts were installed.

A comprehensive tune-up check list, showing checks and adjustments, in the proper order, should be used. Such a list will speed the tune-up by preventing duplication. It will also eliminate waste of time by doing the jobs in improper order. For example, if emission levels are checked before setting timing and/or idle speed, they will have to be redone following any changes.

A sample check list is included in the latter part of this chapter.

ENGINE MECHANICAL CONDITION IS CRITICAL

Before the tune-up preliminary steps, check the compression in all cylinders. If the compression (or cylinder leakage) test indicates a doubtful condition, be sure to inform the owner of the need for internal repairs before proceeding with the tune-up.

There will be cases where, even though the mechanical condition of the car is poor, the owner will want to go ahead with basic tune-up to keep the car running.

If the engine fails in the compression test, run a cylinder leakage test to determine just where the trouble lies. (Directions for conducting a compression test, cylinder leakage test, vacuum test, and cylinder balance test are included in this chapter.)

Remember that sticking valves or rings, especially in a car with relatively low mileage, will often free up if break-in oil is added to the crankcase. Do not feed the oil through the carburetor on catalytic converter equipped cars. Operate the car for a reasonable period of time to free the valves or rings.

Before recommending an engine teardown, make certain it is needed. By the same token, if an overhaul is needed, recommend that it be done before the tune-up.

MAKING COMPRESSION TEST

Operate the engine until normal operating temperature is reached. Remove the spark plugs (See Ignition System Service chapter for correct removal and installation technique.). Remove the air cleaner. Block the throttle valve in the wide open position. The choke must also be fully opened.

Ground the distributor end of the coil secondary wire. Attach a remote starter control. If key switch will be damaged by remote cranking when in the lock or off position, turn the key on.

Insert a compression gauge TIGHTLY in the spark plug hole or port. Crank the engine (battery must be fully charged, in good condition, and properly connected). Starter must spin engine as specified until the gauge shows no further rise in pressure. This will require at least 4 or 5 COMPRESSION strokes. See Fig. 25-5.

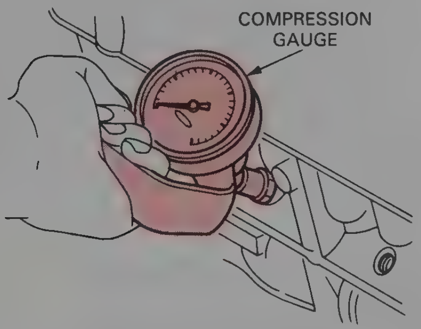


Fig. 25-5. Using a compression gauge to check gasoline engine mechanical condition (valves, rings). (Nissan)

Normally, the first compression stroke will run the gauge indicator needle a considerable distance up the scale. Succeeding strokes will raise it more until the highest level is shown. Record the highest reading for each cylinder.

For engines having plug holes that are difficult to reach, a compression gauge having an offset tip or one utilizing a flex hose, is useful. Look at Fig. 25-6.

Remember that the engine must be at operating temperature and the choke and throttle valves must be open.

When checking compression on diesel engines, remember that compression levels will be considerably higher. Note in Fig. 25-7 that the gauge is not hand held but is securely attached. Some setups bolt the gauge adapter in place while others thread the gauge into a glow plug opening. Follow manufacturer's recommendations.

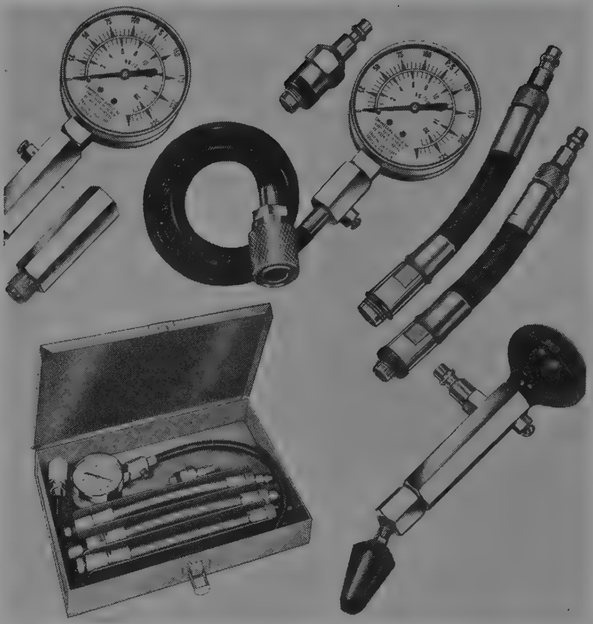


Fig. 25-6. Compression gauges designed for hard to reach spark plug holes or ports. (Snap-On Tools Corp.)

INTERPRETING COMPRESSION READINGS

Examine the readings for all cylinders. Generally, pressure variation between the highest and lowest cylinders should not exceed 10-15 psi (69-103 kPa). This figure depends on engine design, compression ratio, etc. Some manufacturer's specifications permit even greater variation.

Variations between cylinders will have a more adverse effect upon engine performance than overall readings that are even but slightly below specifications.

When taking compression readings, watch the action of the gauge needle. When it raises only a small amount on the first stroke and little more on succeeding strokes, ending up with a very LOW reading, burned, warped, or sticky valves are indicated.

A low buildup on the first stroke with a gradual

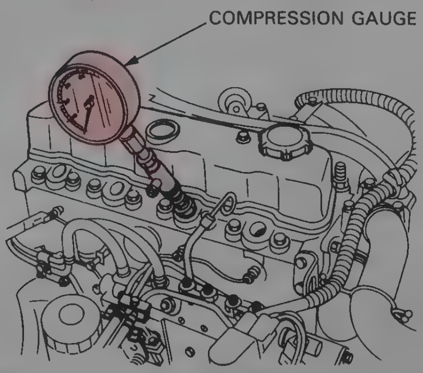


Fig. 25-7. Diesel engine compression gauge. This gauge is firmly attached to provide a positive leakproof seal. (Datsun)

buildup on succeeding strokes, to a moderate reading, can mean worn, stuck, or scored rings.

If two adjacent cylinders are low, a blown head gasket or warped head-to-block surface could be responsible.

Add one tablespoon of heavy (30W minimum) engine oil to a GASOLINE engine cylinder with a low reading. On DIESEL engines, WHERE RECOMMENDED, a VERY SMALL amount of oil can be added. Diesel engines have very high compression. When on top dead center, there is an absolute minimum of space between the piston and cylinder head. An excess amount of oil can cause serious engine damage because the oil will not compress. Some diesel makers forbid the use of ANY oil! Follow manufacturer's recommendations. Crank the engine for a few extra compression strokes and watch the gauge. If the compression goes up a noticeable amount, worn rings are indicated. If the addition of the oil produces no significant change, valve trouble, a broken piston, or a blown gasket is probably causing the low reading.

If the compression pressure exceeds specifications, the engine has probably been modified to increase the compression. There could also be a buildup of carbon on the head of the piston and on the combustion chamber walls. IF CARBON BUILDUP IS CAUSING PINGING THAT CANNOT BE STOPPED BY RETARDING THE TIMING OR BY SWITCHING TO A HIGHER OCTANE GASOLINE, THE CARBON SHOULD BE REMOVED.

Another sign of excessive carbon is "dieseling" (engine continues to run after ignition is turned off). Dieseling action can be caused by glowing bits of carbon. Hard cranking can also indicate excessive compression from carbon buildup.

CYLINDER LEAKAGE DETECTOR

When a cylinder produces a low reading, the use of a cylinder leakage detector will be helpful in pinpointing the exact cause.

The leakage detector is inserted in the spark plug hole. Then the piston is brought up to dead center on the compression stroke. Compressed air is then admitted.

Once the combustion chamber is pressurized, a special gauge will read the percentage of leakage. Refer to Fig. 25-8. Leakage exceeding 20 percent is considered excessive.

While the air pressure is retained in the cylinder, listen for the hiss of escaping air. A leak by the intake valve will be audible in the carburetor. A leak by the exhaust valve can be heard at the tail pipe. Leakage past the rings will be audible at the road draft tube, or at the PCV (positive crankcase ventilation) connection. If air is passing through a blown gasket to an adjacent cylinder, the noise will be evident at the plug hole of the cylinder into which the air is leaking. Cracks in the block or gasket leakage into the cooling system may be detected by a stream of bubbles in the radiator.

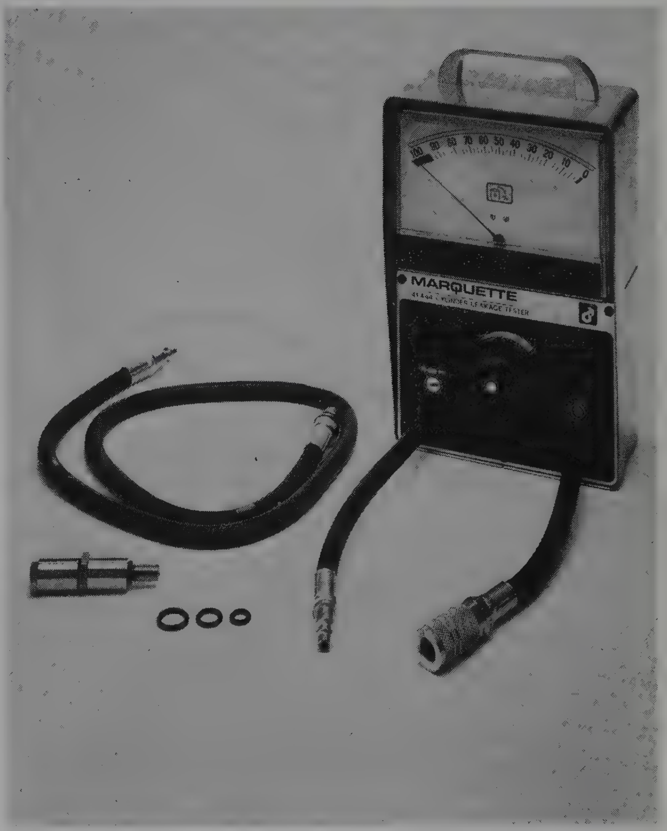


Fig. 25-8. One type of cylinder leakage test tool. (Marquette)

VACUUM GAUGE

A vacuum gauge is a useful diagnostic and tune-up tool. It can be used to set the carburetor idle mixture, to detect vacuum leaks, sticking valves, worn rings, clogged exhaust, and incorrect timing.

Great care, however, must be used in interpreting the readings and actions of the gauge indicator needle. In many instances, the readings will imply several possible problems. Further checking will be required to isolate the exact cause.

The vacuum reading for a given engine can be affected by carburetor adjustment, ignition timing, valve timing, condition of valves and guides, cylinder wear, pistons or rings, vacuum leaks, PCV, and spark plug adjustment.

ATTACHING VACUUM GAUGE

When possible, connect the vacuum gauge to the intake manifold. Some manifolds incorporate a plug that may be removed so a vacuum line adapter may be installed. If no opening is provided, connect to the windshield wiper hose connection (disconnect vacuum booster is used). If the wiper is electric, connect to some other vacuum operated unit fitting. See Fig. 25-9.

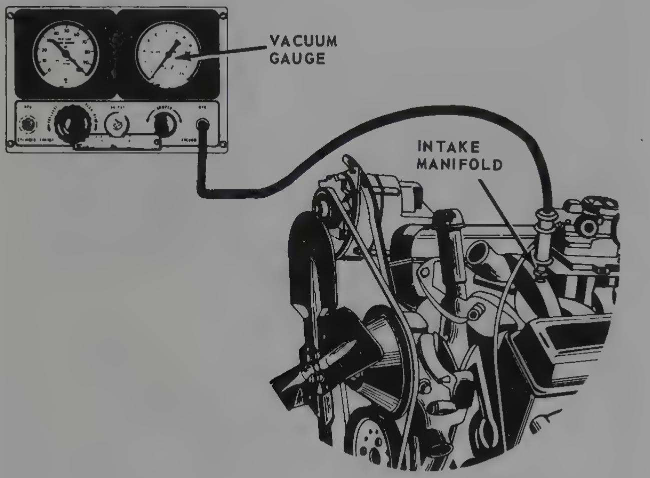


Fig. 25-9. Vacuum gauge connected to engine intake manifold.

CRANKING VACUUM TEST

The engine must be at normal operating temperature. Connect vacuum gauge, as shown in Fig. 25-9. Back off the idle speed screw to allow the throttle valve to fully CLOSE. Ground coil high tension wire. Crank engine and average readings. Cranking speed must be up to specifications.

A relatively steady (some pulsation is normal), high vacuum reading indicates an absence of vacuum leaks and good ring and valve action. A low, but fairly steady reading, can mean vacuum leaks, worn intake valve guides, poor compression, valve timing off, and other problems.

An erratic (uneven) reading can point to burned or sticky valves, damaged piston, or blown gasket.

If the cranking vacuum test indicates problems, conduct a cylinder leakage test. If lacking this equipment, conduct a compression test.

VACUUM TEST — ENGINE RUNNING

Bring the engine to normal operating temperature. Connect vacuum gauge to the intake manifold. Run engine at specified idle speed.

The vacuum gauge should read between 15 and 22 in./Hg. depending upon the engine and the altitude at which the test is performed. SUBTRACT ONE INCH FROM THE SPECIFIED READING FOR EVERY 1,000 FEET OF ELEVATION ABOVE SEA LEVEL.

Late model engines utilizing high lift cams and considerable valve overlap, tend to produce a lower and more erratic vacuum reading.

The reading should (unless cam design prohibits it) be quite steady. It may be necessary to adjust the gauge damper until needle moves easily without excessive flutter.

INTERPRETING VACUUM GAUGE READINGS

A careful study of the vacuum gauge reading while the engine is idling will help to pinpoint trouble areas. Always conduct other appropriate tests before arriving at a final diagnostic decision. Remember that vacuum gauge readings, although helpful, must be interpreted with care.

Fig. 25-10 pictures a number of vacuum gauge readings. Note that the gauge area from 15 to 22 in. is marked in color. This is the normal range. Check manufacturer's specifications for exact readings.

The problems which follow (typical) are numbered 1 through 16. These numbers correspond to numbers in Fig. 25-10. Read the numbered problem description and then study the gauge reading of the same number.

1. NORMAL READING: Needle between 15 and 22 in. and holding steady.
2. NORMAL READING DURING RAPID ACCELERATION AND DECELERATION: When engine is rapidly accelerated (dotted needle) nee-

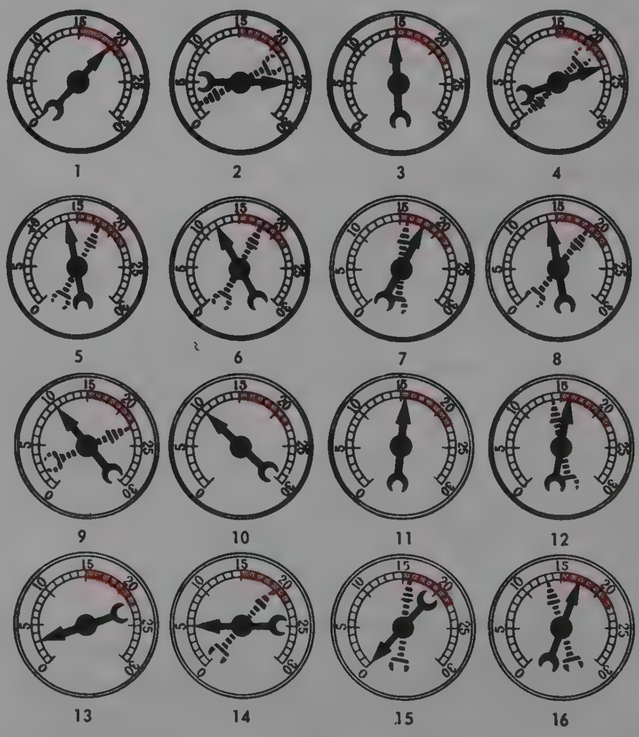


Fig. 25-10. Typical vacuum gauge readings. (Datsun)

dle will drop to a low (not to 0) reading. When throttle is suddenly released, the needle will snap back up to a higher than normal figure.

3. NORMAL FOR HIGH LIFT CAM WITH LARGE OVERLAP: Needle will register as low as 15 in. but will be relatively steady. Some oscillation is normal.
4. WORN RINGS OR DILUTED OIL: When engine is accelerated (dotted needle) needle drops to 0 in. Upon deceleration, needle runs lightly above 22 in.
5. STICKING VALVE OR VALVES: When the needle (dotted) remains steady at a normal vacuum but occasionally flicks (sharp, fast movement) down and back about 4 in., one or more valves may be sticking.
6. BURNED OR WARPED VALVES: A regular, evenly spaced downscale flicking of the needle indicates one or more burned or warped valves. Insufficient tappet clearance will also cause this action.
7. POOR VALVE SEATING: A small but regular downscale flicking can mean one or more valves are not seating.
8. WORN VALVE GUIDES: When the needle oscillates (swings back and forth), over about a 4 in. range at idle speed, the valve guides could be worn. As engine speed is increased, needle will become steady if guides are responsible.
9. WEAK VALVE SPRINGS: When the needle oscillation becomes more violent as engine rpm is increased, weak valve springs are indicated. The reading at idle could be relatively steady.
10. LATE VALVE TIMING: A steady but low reading could be caused by late valve timing.
11. IGNITION TIMING RETARDING: Retarded ignition timing will produce a steady but somewhat low reading.
12. INSUFFICIENT SPARK PLUG GAP OR DEFECTIVE BREAKER POINTS: When plugs are gapped too close, or when the distributor points are defective, a regular, small pulsation of the needle can occur.
13. INTAKE LEAK: A low, steady reading can be caused by an intake manifold or carburetor mounting flange gasket leak.
14. BLOWN HEAD GASKET: A regular drop of fair magnitude can be caused by a blown head gasket or warped head to block surface.
15. CLOGGED EXHAUST SYSTEM: When the engine is first started and is idled, the reading may be normal but as the engine rpm is increased, the back pressure caused by a clogged muffler or

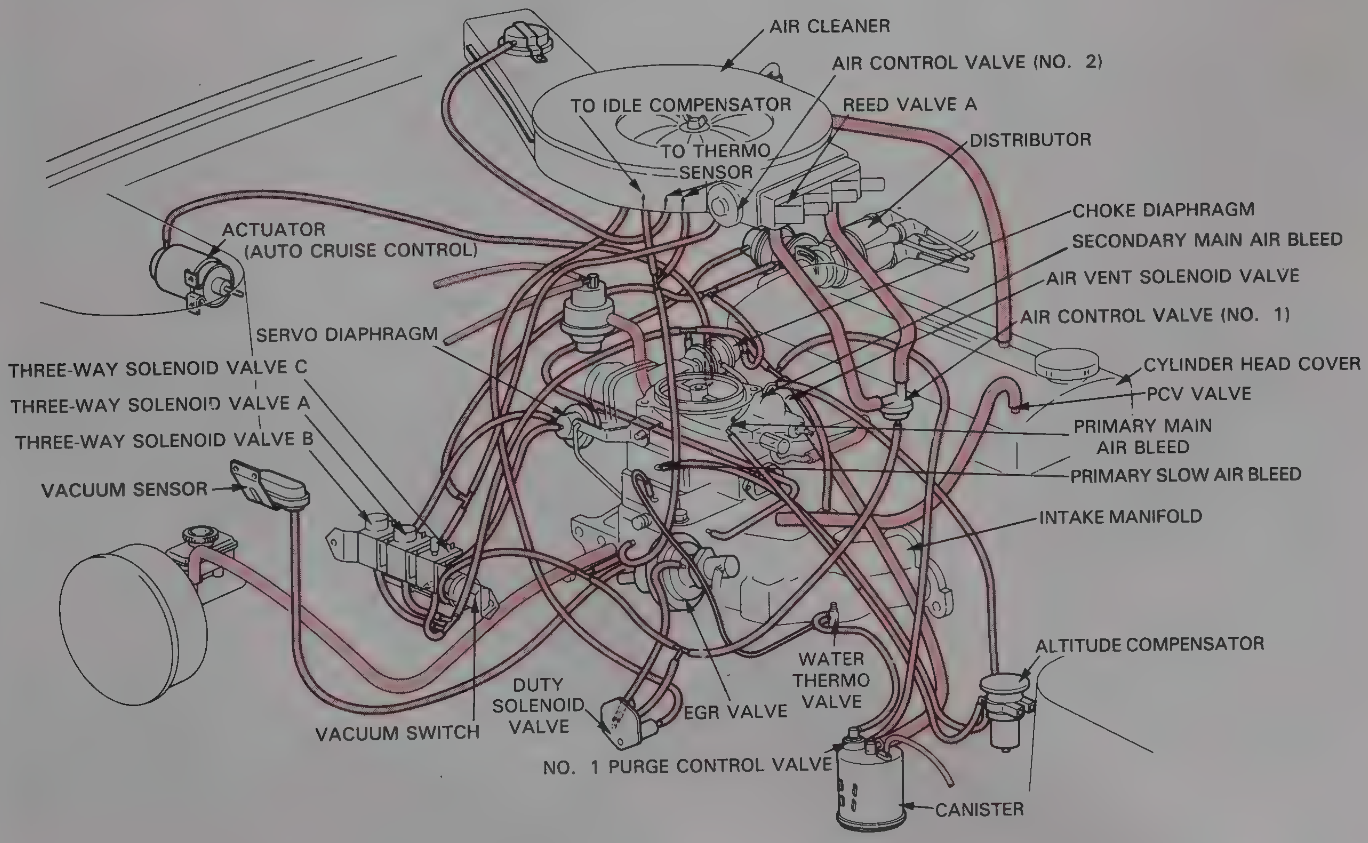

AIR CLEANER
AIR CONTROL VALVE (NO. 2)
TO IDLE COMPENSATOR
REED VALVE A
DISTRIBUTOR
TO THERMO SENSOR
ACTUATOR (AUTO CRUISE CONTROL)
CHOKE DIAPHRAGM
SECONDARY MAIN AIR BLEED
AIR VENT SOLENOID VALVE
AIR CONTROL VALVE (NO. 1)
SERVO DIAPHRAGM
THREE-WAY SOLENOID VALVE C
THREE-WAY SOLENOID VALVE A
THREE-WAY SOLENOID VALVE B
CYLINDER HEAD COVER
PCV VALVE
PRIMARY MAIN AIR BLEED
PRIMARY SLOW AIR BLEED
VACUUM SENSOR
INTAKE MANIFOLD
ALTITUDE COMPENSATOR
WATER THERMO VALVE
DUTY SOLENOID VALVE
EGR VALVE
VACUUM SWITCH
NO. 1 PURGE CONTROL VALVE
CANISTER

Fig. 25-11. Modern engines make use of many vacuum lines and fittings. All must be in good condition, in the proper location, and firmly attached. (Datsun)

kinked tail pipe will cause the needle to slowly drop to 0. The needle then may rise slowly. Excessive exhaust clogging will cause the needle to drop to a low point even if the engine is only idled.

16. IMPROPER CARBURETOR ADJUSTMENT: If the carburetor idle mixture is poorly adjusted, the needle will move slowly back and forth. By adjusting the idle mixture needle valves, the rolling needle motion will stop.

THESE EXAMPLES ARE TYPICAL. THE INFORMATION, IF USED WITH CARE, SHOULD BE HELPFUL IN LOCATING TROUBLE ON ACTUAL JOBS.

VACUUM LEAKS ARE INJURIOUS

The modern engine makes a wide use of vacuum lines with numerous fittings. The potential for leaks is thus increased. Careful inspection is needed. Look at Fig. 25-11.

Excess air leaking into the system will upset the fuel mixture. Vacuum leaks can cause trouble such as rough idle, missing on acceleration, and burned valves. If the leak exists in some accessory unit, such as the power brake, vacuum advance, the unit will not function correctly. FIX VACUUM LEAKS.

CYLINDER BALANCE TEST

To test cylinder balance, compare vacuum and rpm readings with engine at normal temperature on two cylinders at a time. Test reveals engine mechanical condition and efficiency.

CAUTION: Do not test cars with catalytic converters. Misfiring will let unburned fuel enter converter, causing catalyst to overheat.

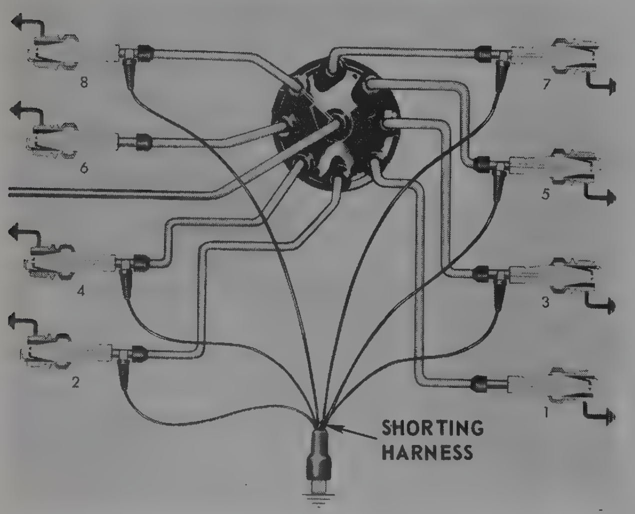


Fig. 25-12. Shorting harness for conducting cylinder balance test on V-8 engine. Note that engine is forced to operate on TWO cylinders. (Chevrolet)

Attach a vacuum pump, tachometer, and a cylinder shorting harness as shown in Fig. 25-12.

Connect the harness wires by using the following formula to indicate which two cylinders form the "pair" that will operate the engine.

Write down the firing order, A, Fig. 25-13. Divide the firing order in two parts, B. Place the first half over the last half, C. Select pairs by reading in a vertical direction, D, Fig. 25-13.

TYPICAL CYLINDER FIRING ORDER = 153624

A 153624

B 153—624

C $\frac{153}{624}$

D $\frac{153}{624}$ ↓↓↓

PAIRS OF CYLINDERS TO BE USED FOR BALANCE TEST { 1 & 6, 5 & 2, 3 & 4

Fig. 25-13. Using engine firing order to select correct pairs of cylinders to conduct cylinder balance test.

With the engine operating at 1500 rpm, short out all cylinders but the selected pair. Jot down the rpm and vacuum reading.

Change the harness connections to operate another pair. Repeat the process until all pairs have been checked. Note rpm and vacuum readings for each pair.

The readings should be about the same for each of the pairs. A significant drop in rpm (about 40 rpm) or in the vacuum reading (about 1 in.) for any pair, indicates that an unbalanced condition is present.

IMPORTANT PRELIMINARY CHECKS

After checking engine mechanical condition, but before the tune-up proper, SEVERAL IMPORTANT PRELIMINARY CHECKS MUST BE MADE. Failure to perform these vital checks until later on in the tune-up procedure may upset much of the tune-up work preceding them. For example: suppose the carburetor air cleaner is clogged. If the idle mixture and idle speed are set first and THEN the cleaner is replaced (or cleaned), both adjustment will be wrong.

The units involved in these preliminary checks, if faulty (dirty, loose, adjusted wrong) can produce a variety of apparent faults in other related units. Once again, failure to make the preliminary checks can waste much time chasing faults that are actually nonexistent.

PRELIMINARY CHECKS

1. AIR CLEANER: Remove, clean, or replace air cleaner as needed. Check gaskets and install.

2. DRIVE BELTS: Check all drive belts for condition and tension.
3. EXHAUST HEAT CONTROL VALVE: Check heat control valve for free operation.
4. PCV AND EGR VALVES: Clean or replace valves. Install and check operation.
5. VALVE TAPPET CLEARANCE: On engines without hydraulic lifters, if the valve tappets have worked loose or if the adjustment has been altered, reset to manufacturer's specifications.
6. BATTERY: Check specific gravity and perform capacity test. Check terminals and wires for voltage drop.
7. OIL AND COOLANT LEVELS: Check the dipstick for the amount and condition of the engine oil. Check the radiator coolant level. Check for sign of serious oil or water leaks. (Make closer check later.)
8. ELECTRICAL CONNECTIONS: Tighten starter, battery, coil primary, ignition switch, voltage regulator, and alternator lead connections.
9. FASTENERS: Tighten intake manifold and carburetor fasteners. If needed, torque head bolts.
10. FITTINGS: Tighten carburetor, fuel pump, and vacuum fittings.

ENGINE MUST BE AT NORMAL OPERATING TEMPERATURE

Before starting the tune-up, make sure that the engine is at normal operating temperature. If the engine is tuned while cold, various adjustments must be

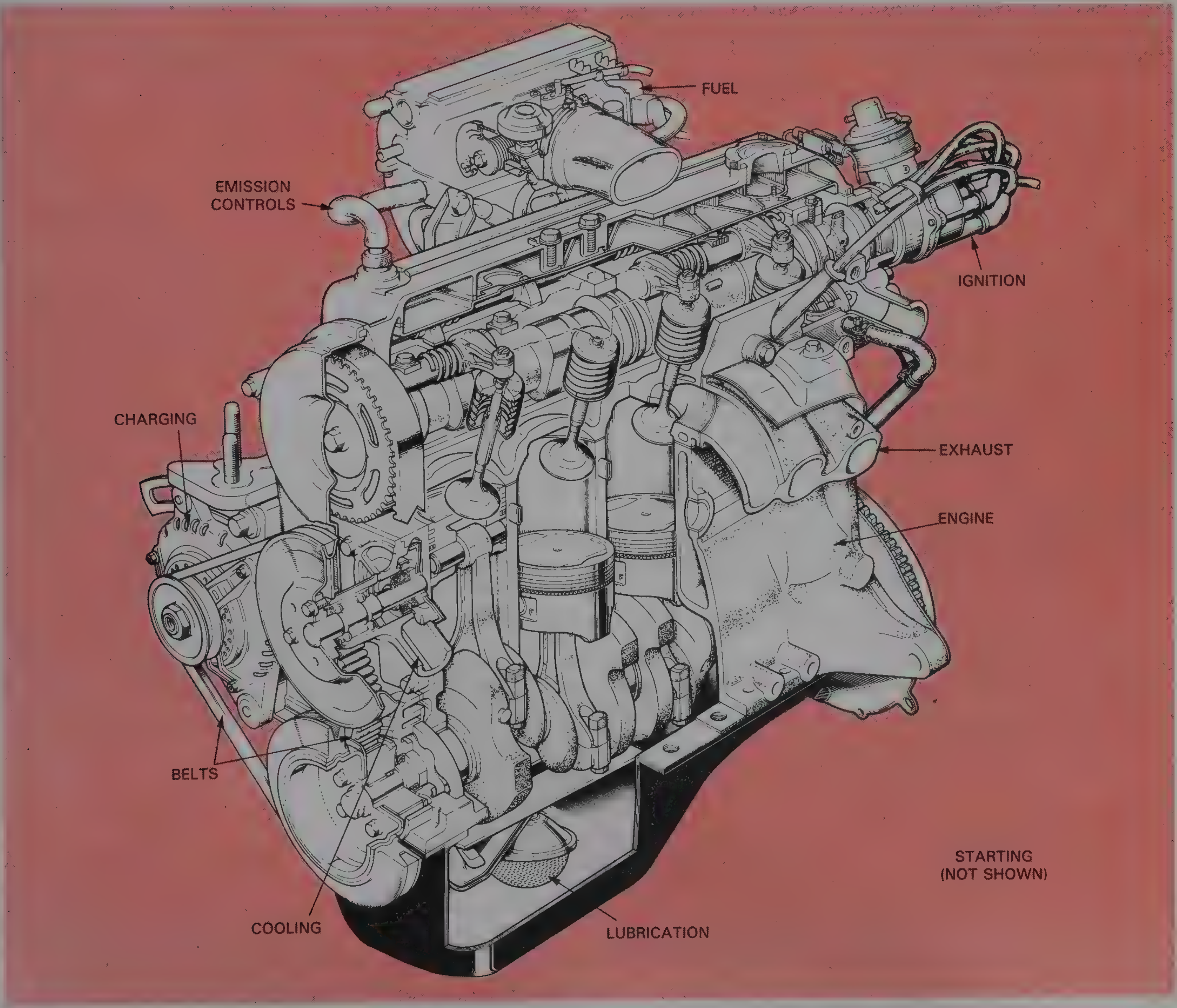


Fig. 25-14. Note the various parts and the systems that should be checked during a major tune-up. (Mazda)

changed when the engine warms up.

WHEN MAKING TUNE-UP CONNECTIONS, KEEP INSTRUMENTS, WIRES, AND FINGERS FREE OF THE FAN AND DRIVE BELTS. KEEP TEST WIRES AWAY FROM THE EXHAUST MANIFOLD.

REFER TO CHAPTER CONCERNED

Tune-up brings together and applies certain tests and adjustments peculiar to both the engine and engine systems — cooling, lubrication, charging, starting, ignition, and fuel.

The techniques involved in making these tests and adjustments are explained in the chapters covering the various systems. IF IN DOUBT AS TO THE EXACT METHOD OF CONDUCTING THE TESTS AND ADJUSTMENTS RECOMMENDED IN THE CHECKLIST WHICH FOLLOWS, REFER TO THE CHAPTER INDICATED.

The systems covered by a thorough tune-up are pictured in Fig. 25-14.

CHECKLIST FOR TUNE-UP OPERATIONS

The following checklist shows the tests, adjustments, and other operations commonly performed during a comprehensive tune-up. The steps are listed in the general order in which they should be done.

Some of the steps may be combined if the proper test equipment is available. For example, if an oscilloscope is used, it will indicate the condition of the plugs, secondary wiring, coil, and other parts in one operation. You can develop your own checklist by basing it on the equipment available and the type of tune-up to be offered.

ALWAYS USE A CHECKLIST TO AVOID DUPLICATION AND TO MAKE SURE NOTHING OF IMPORTANCE IS OVERLOOKED.

CHECKLIST OPERATIONS

STEP	CHAPTER
1. Check prior service record and question owner regarding engine performance.	25
2. Clean and tighten battery terminals. Tighten hold-downs.	24
3. Check battery specific gravity.	24
4. Test battery capacity (load test).	24
5. Operate starter to make certain engine cranks over rapidly enough to perform an accurate compression test. If not, conduct repairs.	24
6. Check oil and coolant level.	19
7. Bring engine to normal operating temperature.	25
8. Remove plugs (gasoline) or nozzles/glow plugs (diesel) and conduct compression test.	25
9. If required, perform cylinder leakage test.	25
10. Inspect, clean, gap, or replace spark plugs.	23
11. Perform preliminary checks on air cleaner, drive belts, PCV valve, EGR valve tappet clearance, exhaust heat control valve, thermostatic air cleaner, electrical connections, fasteners, fittings.	25
12. On older vehicles with a breaker point ignition system, replace distributor points. Gap, align, check point spring pressure, and lubricate cam surface. Check distributor breaker plate ground wire and lead-in primary wire. Set point dwell.	23
13. Check distributor wiring (primary and secondary) for condition, connections, and routing.	23
14. Inspect rotor. Replace if needed. Lubricate wick under rotor where used.	23
15. Clean and inspect distributor cap. Replace if needed. Note: If the cap is replaced, replace the rotor also. If the rotor is replaced, replace the cap.	23
16. Lubricate distributor as needed.	23
17. Test distributor vacuum advance.	23
18. Test distributor centrifugal advance.	23
19. Inspect coil wiring connections, condition, routing.	23
20. Test coil.	23
21. Set ignition timing.	23
22. Test spark plug polarity.	23
23. On older vehicles with DC generator, lubricate generator as required.	24
24. Check alternator or DC generator output.	24
25. Check charging voltage.	24
26. Check regulator, if required.	24
27. Check charging system wiring for excessive resistance, if required.	22, 24
28. If required, conduct suitable starter system tests.	22, 24
29. Check action of the starting neutral safety switch.	22, 24
30. Clean fuel vapor canister filter.	20, 25
31. Check operation of thermostatically controlled air cleaner. Check air cleaner filter(s).	20, 35

Checklist Operations continued

STEP	CHAPTER
32. Clean or replace fuel filter or filters.	20
33. If used, clean filter sediment bowl. Check flex hose.	20
34. Test fuel pump for pressure and volume.	20
35. Check automatic choke for correct setting and action.	21
36. Check fast idle system.	21, 22
37. Check and adjust carburetor or fuel injection idle speed and mixture.	21, 22
38. Where used, check throttle return dashpot for operation and adjustment.	21
39. Check operation of carburetor accelerator pump.	21
40. On diesel engines, check injector pump timing.	22
41. Analyze combustion gases.	25, 35
42. Check radiator and heater hoses, core hole plugs, and transmission cooling lines for leakage.	19
43. Pressure test radiator cap and radiator.	19
44. Check fan, air ducts, fins, and thermostatic control on air-cooled cars.	19
45. Inspect exhaust system for leaks.	35
46. Check for leakage of engine oil, power steering, brake fluid, coolant.	17, 19, 31, 33
47. Inspect emission (smog) control devices*.	35
48. ROAD TEST VEHICLE.	25
49. Final inspection for leaks.	17, 19, 31, 33
50. Clean car. Fill out service record and deliver vehicle to owner.	
51. Discuss the job and answer any questions the customer may have.	
* Some emission control systems are closely tied in with both fuel and ignition systems. They should be checked and adjusted in the order specified by the manufacturer. MAKE CERTAIN CAR EXHAUST EMISSION LEVELS COMPLY WITH LEGAL REQUIREMENTS!	

EXHAUST GAS ANALYZER

The exhaust gas analyzer samples exhaust gas to determine the level of certain emissions, such as CO (carbon monoxide) HC (hydrocarbons). It will very accurately determine the ratio of gasoline to air. It can thus be used to check fuel system efficiency at all speeds.

The engine should be at normal temperature with the choke fully open. Insert the pickup pipe into the tail pipe. The exhaust system must be leakproof to prevent dilution of the exhaust gas.

If the engine is burning oil, or if gum removing solvents are being fed into the carburetor, do not use the analyzer as the readings will be inaccurate. The engine must be in sound mechanical condition with good plugs and ample plug voltage. Ignition timing must be correct.

Follow manufacturer's instructions carefully as this test requires great care to produce usable results. See Fig. 25-15.

ROAD TESTING

No tune-up can be considered complete until the car has been road tested.

Use the road test to check for smooth, responsive, ping-free acceleration. Operation must be smooth (no missing, bucking, or loping) at low, meduim, and high speed. Engine should not stall following a fast stop. Check operation of dash instruments. Upon returning to the shop, make a final inspection for water, fuel, or oil leaks.

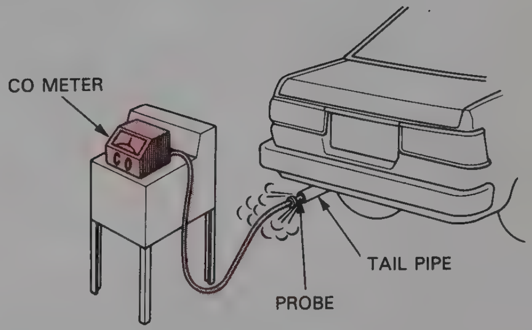


Fig. 25-15. Using an exhaust gas analyzer, in this case a single CO meter, to check level of carbon monoxide. A different gauge will be used to check hydrocarbon levels. Note how probe is inserted into tail pipe. (Toyota)

In addition to checking all engine systems, the road test offers an opportunity to check the brakes, transmission, steering, clutch, and rear axle. Although repairs to these areas are not within the realm of a tune-up, it is well to call the owner's attention to any such work needed.

Many shops also test the horn, head lamps, backup lights, and signal lights before delivery. This takes little time and will help build customer goodwill.

For road testing, select an area where the car may be driven at various speeds, accelerated rapidly, and braked abruptly. Be careful, and OBEY ALL TRAFFIC LAWS. Treat the customer's car as though it were your own — remember that you are responsible for it until delivered.

CHASSIS DYNAMOMETER "ROAD TEST"

The use of a chassis dynamometer instead of a regular road test on the streets has some advantages. It saves time, eliminates the possibility of accidents, and provides checks such as torque and speedometer accuracy. These checks may not be possible during an actual road test. It will also permit the use of tune-up instruments while the engine is driving the car.

In making a dynamometer test, the car is parked on the dynamometer with the drive wheels resting on rollers. See Fig. 25-16. The controls are connected to the engine and the engine is started. The transmission is placed in gear. The drive wheels spin the rollers. Note the use of a safety stop, Fig. 25-16.

By placing a load on the rollers, the engine is forced to "pull" as though the car were actually on the road.

The chassis dynamometer provides a handy and accurate method of quickly and thoroughly road testing a car right in the shop.

SERVICING EMISSION CONTROL DEVICES AND SYSTEMS

Cars are equipped with numerous emission control devices and systems. These controls must be checked out to insure proper performance and fuel economy. One such system (air injection) is shown in Fig. 25-17.

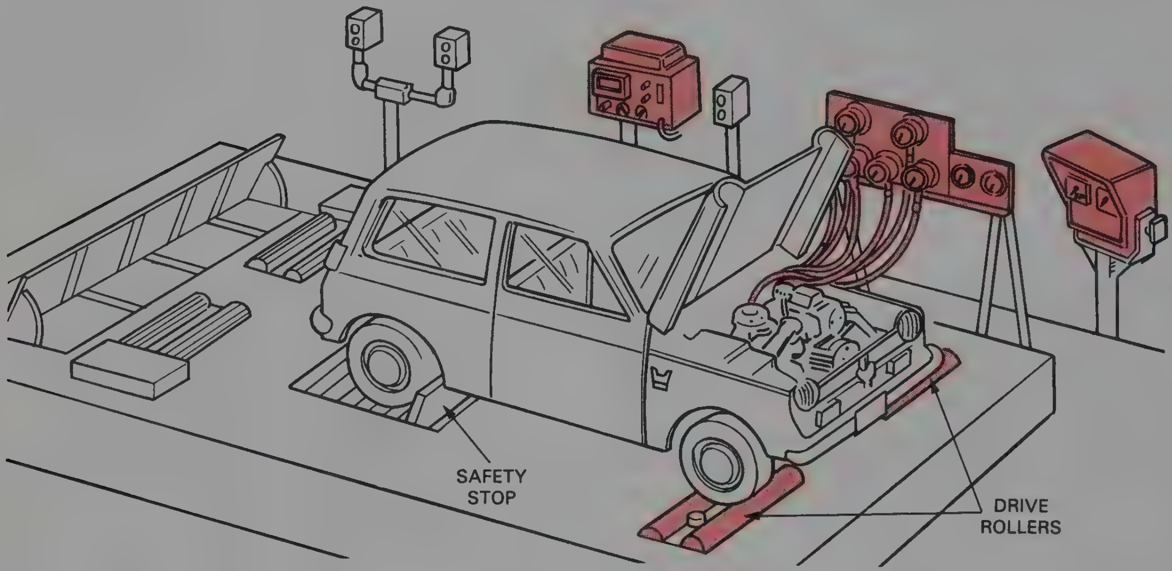

SAFETY
STOP
DRIVE
ROLLERS

Fig. 25-16. Simulated road testing in the shop is possible with a chassis dynamometer. With such a setup, a large number of very useful tests can be conducted. (Honda)

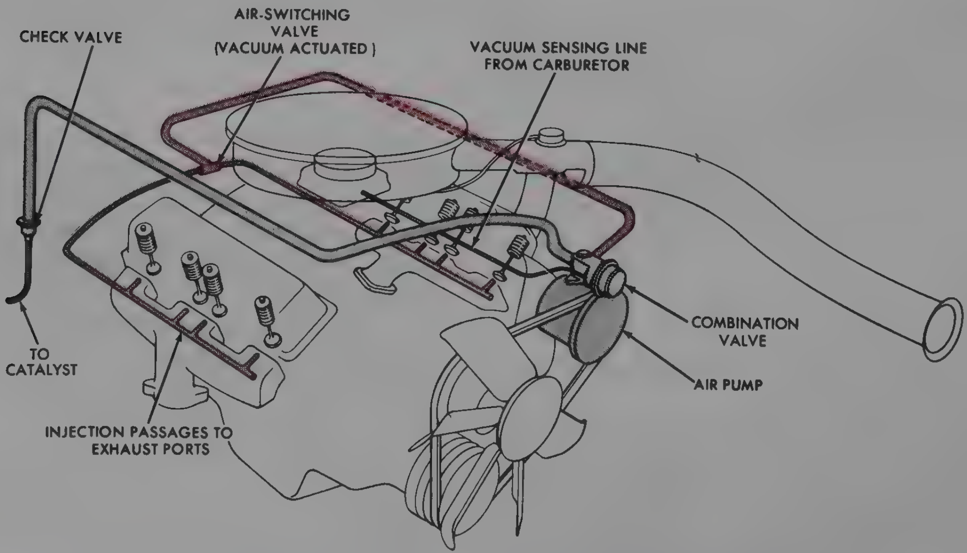

CHECK VALVE
AIR-SWITCHING
VALVE
(VACUUM ACTUATED)
VACUUM SENSING LINE
FROM CARBURETOR
TO
CATALYST
COMBINATION
VALVE
AIR PUMP
INJECTION PASSAGES TO
EXHAUST PORTS

Fig. 25-17. Air injection system used on a V-8 engine. (Chrysler)

Following a check of all emissions systems, and the completion of the entire tune-up, use proper test tools to make certain that the exhaust emission levels comply with legal requirements. See Figs. 25-3 and 25-15.

Each vehicle has an informative underhood decal that lists very important tune-up and emission information for THAT SPECIFIC VEHICLE AND ENGINE. Fig. 25-18 illustrates one such decal.

When selecting replacement parts, make certain they are compatible with the system being serviced.

If the engine checks out OK, perform the preliminary checks on the air cleaner, drive belts, PCV valve, tappet clearance, electrical connections, fasteners, and fittings before starting the tune-up.

The engine must be at normal operating temperature for all tune-up operations. Use care to avoid injury to the equipment or to yourself from the fan or drive belts.

An exhaust gas analyzer is handy for checking fuel system efficiency at all speeds.

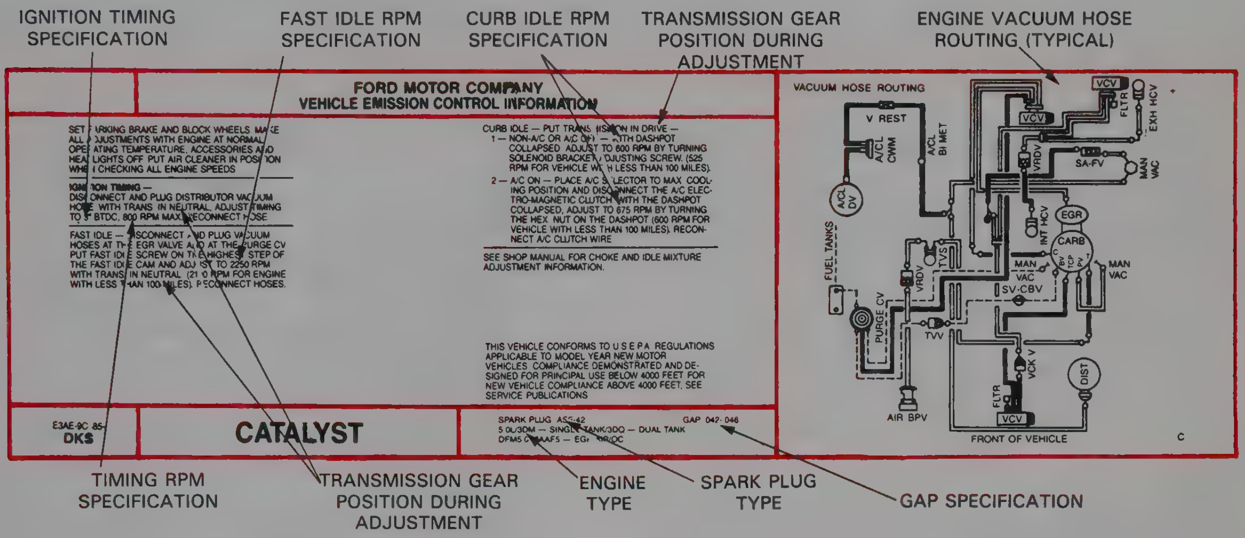

IGNITION TIMING SPECIFICATION
FAST IDLE RPM SPECIFICATION
CURB IDLE RPM SPECIFICATION
TRANSMISSION GEAR POSITION DURING ADJUSTMENT
ENGINE VACUUM HOSE ROUTING (TYPICAL)
FORD MOTOR COMPANY
VEHICLE EMISSION CONTROL INFORMATION
VACUUM HOSE ROUTING
CATALYST
FRONT OF VEHICLE
TIMING RPM SPECIFICATION
TRANSMISSION GEAR POSITION DURING ADJUSTMENT
ENGINE TYPE
SPARK PLUG TYPE
GAP SPECIFICATION

Fig. 25-18. A typical underhood decal listing important factory tune-up and emission control information for a specific vehicle-engine combination. (Ford)

SUMMARY

Tune-ups, to be most effective, should be comprehensive. The shop should be equipped with accurate test equipment. All essential instruments should be available.

Always use factory specifications for the exact type, model, and year of car at hand.

Use quality replacement parts.

Ask the owner for comments regarding car performance. If he, or she, is somewhat vague, try to help by asking questions designed to locate trouble spots.

Follow a tune-up checklist to avoid duplication and possible omission of important steps.

Keep records showing parts installed, date, mileage, etc. Use any available prior service records to help you before starting the tune-up.

Make certain the engine is in a mechanical condition that will warrant a tune-up. General engine condition can be determined in a number of ways — compression test, cylinder leakage test, vacuum test, and cylinder balance test.

Make sure that your diagnosis is correct before recommending engine work prior to starting the tune-up service procedures.

Always road test a car following a tune-up. If available, a chassis dynamometer may be used instead of actual road testing.

Be certain to check out all emission control devices for proper operation. Check exhaust emission levels for compliance with emission regulations.

GOOD WORK HABITS ARE IMPORTANT

The top mechanic arrives at work ON TIME and is absent only for GOOD REASONS. If absence is necessary, the mechanic will immediately NOTIFY the employer so that customer commitments and work loads may be adjusted.

Good mechanics invariably are hard workers. During any periods when they may not have work assignments, they will busy themselves by cleaning tools, maintaining equipment, sweeping the work station, or helping fellow mechanics. They take PRIDE IN THEIR WORK AND PRIDE IN THE BUSINESS. They know that by helping the business to prosper, they too will prosper.

Top mechanics devote time and energy toward the betterment of the trade. They gladly share their knowledge with apprentices. They conduct themselves, at all times, in a way that brings credit to the trade.

ENGINE AND ENGINE SYSTEM PROBLEM DIAGNOSIS

The following charts list major problems, possible causes, and suggested corrections. Obviously, some problems have more than one cause. In such cases, each cause must be properly identified and applicable corrections made.

Keep in mind that emission control systems have a profound effect on the ignition, carburetion, etc., systems and must be checked out when making a problem diagnosis. (See emission system diagnosis in the chapter on "Emission Control.") Some systems have diagnostic plug-in connectors. Use proper instruments.

Note that the problems are arranged by system — fuel, lubrication, and ignition.

At the end of this section, brief coverage is given to the identification and correction of common engine and accessory noise problems.

LUBRICATION SYSTEM PROBLEM DIAGNOSIS
PROBLEM: LOW OIL PRESSURE

Possible Cause	Correction
1. Low oil level.	1. Add oil.
2. Oil diluted.	2. Change oil.
3. Camshaft, main or connecting rod bearings worn.	3. Install new bearings.
4. Oil pump worn.	4. Replace or rebuild oil pump.
5. Pressure relief valve spring weak.	5. Replace spring or add washers.
6. Crankshaft or camshaft journals worn.	6. Grind journals.
7. Oil pump intake clogged.	7. Clean screen, pipe, and tighten connection.
8. Oil line connection leak.	8. Tighten connection.
9. Defective gauge (direct pressure type).	9. Replace gauge.
10. Defective sender or gauge (electric type).	10. Replace sender or gauge.
11. Improperly installed bypass oil filter.	11. Install correctly.
12. Low idle speed.	12. Set speed to specs.
13. Plugged oil filter.	13. Replace filter and oil.
14. Hole in oil pickup pipe.	14. Replace pipe.
15. Oil galleys clogged.	15. Clean out or replace block.
16. Loose or missing oil galley plugs.	16. Tighten and/or install plugs.
17. Improper oil viscosity.	17. Use proper viscosity oil.

PROBLEM: EXCESSIVE OIL PRESSURE

Possible Cause	Correction
1. Oil too viscous (heavy).	1. Change to lighter oil.
2. Pressure relief valve spring under too much tension.	2. Reduce spring pressure.
3. Pressure relief valve stuck.	3. Clean valve.
4. Main oil line from pump clogged.	4. Clean line.
5. Defective gauge (direct pressure type).	5. Replace gauge.
6. Defective sender or gauge (electric type).	6. Replace sender or gauge.

PROBLEM: ENGINE OIL CONTAMINATION

Possible Cause	Correction
1. Blow-by—rings worn.	1. Install new rings.
2. Blow-by—excessive piston or cylinder wear.	2. Rebore and install new pistons.
3. Coolant entering oil—cracked block or head.	3. Seal leak or replace part. Drain oil. Flush, and refill crankcase.
4. Coolant entering oil—blown head gasket.	4. Replace gasket. Check head and block surface. Drain oil. Flush and refill crankcase.
5. Fuel entering oil—excessive choking.	5. Adjust choke.
6. Fuel entering oil—float level too high.	6. Adjust float level.
7. Fuel entering oil—float valve leaks.	7. Replace float valve needle and seat.
8. Fuel entering oil—fuel pump diaphragm cracked.	8. Replace diaphragm or pump.
9. Water entering oil—crankcase condensation.	9. Clean road draft tube or PCV valve.
10. Rapid formation of sludge.	10. Clean PCV valve.
11. Rapid formation of sludge.	11. Use detergent oil.
12. Rapid formation of sludge.	12. Raise engine operating temperature if too cold.

PROBLEM: NO OIL PRESSURE

Possible Cause	Correction
1. Oil level too low.	1. Add oil.
2. Oil pump inoperative.	2. Repair or replace pump.
3. Defective gauge (direct pressure type).	3. Replace gauge.
4. Defective sender or gauge (electric).	4. Replace sender or gauge.
5. Wire between sender and gauge disconnected.	5. Connect wire.
6. Pump intake screen or tube clogged.	6. Clean screen and tube.
7. Pressure relief valve stuck.	7. Clean relief valve.
8. Line to sender or gauge clogged.	8. Clean line.

PROBLEM: EXCESSIVE OIL CONSUMPTION

Possible Cause	Correction
1. Oil too light.	1. Change to heavier oil.
2. Oil diluted.	2. Change oil.
3. Oil level too high.	3. Lower oil level.
4. Worn or clogged rings.	4. Install new rings.
5. Excessive piston and cylinder wear.	5. Rebore and install new pistons.
6. Worn valve guides.	6. Replace guides or ream to next oversize stem.
7. Worn valve stems.	7. Replace valves.
8. Cracked diaphragm in combination fuel-vacuum pump.	8. Replace diaphragm or pump.
9. Excessive speed.	9. Reduce speed.
10. Cylinder torque distortion.	10. Torque head fasteners correctly.
11. Worn bearings—excess oil throw-off.	11. Replace bearings.
12. Clogged PCV system.	12. Clean PCV system.
13. Clogged road draft tube.	13. Clean road draft system.
14. Excessive oil pressure.	14. Reduce pressure.
15. Engine running too hot.	15. Reduce operating temperature.
16. Rear main seal leak.	16. Replace seal.
17. Crankshaft front seal leak.	17. Replace seal.
18. Pan gasket leak.	18. Replace gasket or tighten fasteners.
19. Valve cover gasket leak.	19. Tighten fasteners or replace gasket.
20. Timing gear cover leak.	20. Tighten fasteners or replace gasket.
21. Fuel pump flange loose.	21. Tighten fasteners.
22. Oil filter cover leak.	22. Tighten cover or replace gasket.
23. External line leak.	23. Repair or replace line.
24. Oil pan drain plug leak.	24. Tighten or replace gasket.
25. Oil gallery plug loose.	25. Tighten plug.
26. Oil gauge or sender leak.	26. Tighten or replace.
27. Rear camshaft plug leak.	27. Replace plug.
28. Wrong oil ring design.	28. Install correct rings.
29. Rings installed wrong.	29. Install correctly.
30. Glazed cylinder walls—rings will not seat.	30. Hone walls.
31. External leaks.	31. Locate and repair.
32. Piston(s) improperly installed.	32. Install correctly.
33. Improper reading of dipstick.	33. Check with vehicle on level surface. Allow sufficient time to drain down.
34. Damaged turbocharger seals.	34. Replace seals.
35. Loose or broken turbocharger oil feed line(s).	35. Repair or replace as necessary.
36. Leaking oil cooler.	36. Repair or replace.

COOLING SYSTEM PROBLEM DIAGNOSIS

PROBLEM: OVERHEATING

Possible Cause	Correction
1. Coolant level low.	1. Add coolant—check for reason.
2. Drive belt loose.	2. Adjust tension.
3. Drive belt broken.	3. Replace belt.
4. Drive belt glazed or oil soaked.	4. Replace belt.
5. Thermostat stuck closed.	5. Replace thermostat.
6. Pressure cap inoperative.	6. Replace pressure cap.
7. Bugs, leaves, other debris on radiator core.	7. Flush with water—back to front.
8. Rust scale clogging radiator.	8. Clean. Flush. Install inhibitor.

Problem: Overheating continued

Possible Cause	Correction
9. Rust scale clogging in block.	9. Clean. Flush. Install inhibitor.
10. Valve timing off.	10. Set timing.
11. Air leaks into system.	11. Tighten hoses. Repair pump or cracks.
12. Hoses clogged.	12. Replace hoses.
13. Bottom hose collapsed.	13. Replace hose.
14. Low boiling point antifreeze.	14. Change antifreeze or thermostat.
15. Late ignition timing.	15. Adjust timing.
16. Leaking cylinder head gasket.	16. Replace gasket. Check block and head surfaces.
17. Water pump impeller slipping or broken.	17. Replace impeller.
18. Brakes dragging.	18. Adjust brakes.
19. Vehicle overloading.	19. Caution driver.
20. Manifold heat valve stuck or broken.	20. Loosen or repair.
21. Fan speed slow—improper pulley size.	21. Change pulley size.
22. Low engine oil level.	22. Add oil to full mark.
23. Frozen coolant.	23. Thaw. Add antifreeze.
24. Exhaust system back pressure.	24. Change muffler or open up dented pipe.
25. Lean carburetor mixture.	25. Clean carburetor. Install proper size jets.
26. Wrong cylinder head gasket.	26. Install correct gasket.
27. Air leaks into system.	27. Check at pump, lower radiator hose. Check for combustion leak.
28. Ignition timing retarded.	28. Advance ignition.
29. Defective electric fan motor.	29. Replace motor.
30. Defective spark delay valve.	30. Replace valve.
31. Core sand in head or block.	31. Clean or replace.
32. Inoperative fan fluid coupling (fan clutch).	32. Replace coupling.
33. Aftermarket (add on) air conditioner. Standard cooling system.	33. Install heavy duty cooling system parts: radiator, thermostat, etc.
34. Defective electric fan ambient temperature switch.	34. Replace switch.
35. Clogged catalytic converter.	35. Repair or replace.
36. Lean fuel mixture.	36. Adjust mixture.

PROBLEM: OVERCOOLING AND/OR SLOW WARMUP

Possible Cause	Correction
1. Thermostat stuck open.	1. Replace thermostat.
2. Weather extremely cold.	2. Cover a portion of radiator.
3. No thermostat.	3. Install thermostat.
4. Low temperature thermostat.	4. Install high temperature thermostat.

PROBLEM: APPARENT OVERHEATING OR OVERCOOLING

Possible Cause	Correction
1. Faulty temperature sender.	1. Replace sender.
2. Faulty temperature gauge.	2. Replace gauge.
3. Faulty gauge wiring.	3. Clean. Connect and tighten.
4. Complete unit faulty (bulb type).	4. Replace entire unit—gauge, tubing, and bulb.
5. Improper fan size, type, or speed.	5. Replace with correct unit.

PROBLEM: BELT SQUEAL UPON ACCELERATION

Possible Cause	Correction
1. Belt loose.	1. Adjust tension.
2. Belt glazed.	2. Replace belt.
3. Excessive friction in water pump, power steering pump, etc.	3. Repair defective unit.

PROBLEM: BELT SQUEAL AT IDLE

Possible Cause	Correction
1. Belt loose.	1. Adjust tension.
2. Pulleys misaligned.	2. Align pulleys.
3. Uneven pulley groove.	3. Replace pulley.
4. Foreign material on belt.	4. Clean or replace belt.
5. Belt width not uniform.	5. Replace belt.
6. Adjuster loose or broken.	6. Tighten or replace.

PROBLEM: BELT JUMPS FROM PULLEY OR ROLLS OVER IN PULLEY GROOVE

Possible Cause	Correction
1. Belt loose.	1. Adjust tension.
2. Pulleys misaligned.	2. Align pulleys.
3. Broken cords (internal).	3. Replace belt.
4. Mismatched belts.	4. Install matched set of belts.
5. Eccentric pulley.	5. Replace.
6. Loose pulley(s).	6. Tighten or replace.

PROBLEM: NOISY WATER PUMP

Possible Cause	Correction
1. Bearing worn and rough.	1. Repair or replace pump.
2. Seal noisy.	2. Add inhibitor-water pump lube mixture to system.
3. Loose impeller.	3. Rebuild or replace pump.

PROBLEM: BUZZING RADIATOR CAP

Possible Cause	Correction
1. Coolant boiling.	1. Shut engine off and correct cause.

PROBLEM: LOSS OF COOLANT

Possible Cause	Correction
1. Leaking radiator.	1. Repair leak.
2. Leaking hose.	2. Tighten clamp or replace hose.
3. Cracked hose.	3. Replace hose.
4. Overheating.	4. Correct cause.
5. Overfilling.	5. Fill to correct level.
6. Air leak at bottom hose.	6. Tighten clamps or replace hose.
7. Blown head gasket.	7. Replace gasket. Check mating surfaces.
8. Water pump seal leaking.	8. Replace seal or entire pump.
9. Heater core leaking.	9. Repair leak.
10. Cracked block, head, cylinder, etc.	10. Repair or replace.
11. Pressure cap inoperative.	11. Replace cap.
12. Leaking block core hole plugs.	12. Replace plugs.
13. Improper cylinder head tightening.	13. Torque as recommended.
14. Leak at temperature sender.	14. Tighten or replace sender.
15. Leaking surge tank.	15. Repair leak.
16. Leak at fasteners that enter water jacket.	16. Remove fasteners. Cement and replace.
17. Cracked water jacket or thermostat housing.	17. Repair or replace.
18. Damaged coolant recovery bottle.	18. Replace bottle.
19. Leaking petcock.	19. Tighten or replace.

FUEL SYSTEM PROBLEM DIAGNOSIS

NOTE: Consult Chapter 22 for information on fuel injection (gasoline and diesel). See Chapter 35 for coverage of emission related systems.

PROBLEM: NO FUEL DELIVERY

Possible Cause	Correction
1. No fuel.	1. Fill tank.
2. Tank vent(s) clogged.	2. Open vent(s).
3. Tank filter clogged.	3. Clean or replace filter.
4. Fuel lines kinked or clogged.	4. Straighten and/or clean lines.
5. Vapor lock.	5. Cool lines. Change to less volatile gas. Protect lines from heat.
6. Fuel pump(s) inoperative.	6. Rebuild or replace pump(s).
7. Fuel filter or filters clogged.	7. Clean or replace filters.
8. Frozen line.	8. Thaw. Remove water from system.
9. Air leak between fuel pump and tank.	9. Repair leak.
10. Carburetor float valve stuck shut.	10. Loosen and clean valve.
11. Clogged injection pipe(s).	11. Clean or replace pipes.
12. Inoperative injection pump.	12. Repair or replace pump.

PROBLEM: INSUFFICIENT FUEL DELIVERY

Possible Cause	Correction
1. Tank vent partially clogged.	1. Open vent.
2. Tank filter partially clogged.	2. Clean filter.
3. Gas lines kinked or clogged.	3. Straighten or clean lines.
4. Vapor lock.	4. See vapor lock—no fuel delivery.
5. Air leak between fuel pump and tank.	5. Repair leak.
6. Fuel filter partially clogged.	6. Clean or replace filter.
7. Fuel pump check valves worn.	7. Install new valves or pump.
8. Stretched, cracked, or perforated fuel pump diaphragm.	8. Install new diaphragm or pump.
9. Fuel pump-to-block gasket too thick.	9. Reduce gasket thickness.
10. Weak fuel pump spring.	10. Install new spring or pump.
11. Wrong pump.	11. Install correct pump.
12. Worn pump linkage.	12. Rebuild or install new pump.
13. Worn pump link actuating cam or eccentric.	13. Replace cam or eccentric. May install an electric pump.
14. Fuel pump loose.	14. Tighten pump fasteners.
15. Fuel pump body screws loose.	15. Tighten pump body screws.
16. Clogged injection pipes.	16. Clean or replace pipes.
17. Defective injector(s).	17. Repair or replace injector(s).
18. Faulty injection pump.	18. Repair or replace pump.
19. Fuel injection pulse width incorrect.	19. Check control and sensors. Replace as needed.
20. Fuel injection airflow meter malfunction.	20. Repair, adjust, or replace.
21. Defective exhaust sensor.	21. Replace.

PROBLEM: EXCESSIVE FUEL DELIVERY OR PRESSURE

Possible Cause	Correction
1. Fuel pump diaphragm over tensioned.	1. Loosen body screws. Adjust diaphragm and tighten screws.
2. Fuel pump diaphragm spring too strong.	2. Install proper spring.
3. Seized pump link (no free play).	3. Free link.
4. Incorrect pump.	4. Replace.
5. Fuel injection pulse width excessive.	5. Check control and sensors. Replace as needed.
6. Fuel injection pressure regulator malfunctioning.	6. Adjust or replace regulator.
7. Fuel injection control computer defective.	7. Replace control unit.
8. Fuel injection airflow meter malfunction.	8. Repair, adjust, or replace.
9. Defective exhaust sensor.	9. Replace sensor.

PROBLEM: CARBURETOR FLOODING

Possible Cause	Correction
1. Defective inlet needle valve.	1. Replace inlet needle valve and seat.
2. Float level too high.	2. Adjust float level.
3. Dirty inlet needle.	3. Clean valve, fuel lines, and filters.
4. Excessive fuel pressure.	4. Reduce pressure.
5. Float sunk.	5. Repair or replace float.
6. Float binding.	6. Align float.
7. Heavy fuel flow pulsations.	7. Replace pulsation damper. Install pulsation damper.
8. Internal circuit leakage.	8. Repair or replace carburetor.

PROBLEM: IMPROPER CHOKING

Possible Cause	Correction
1. Choke thermostatic spring tension adjusted wrong.	1. Adjust spring tension.
2. Choke vacuum break inoperative or improperly adjusted.	2. Adjust or replace.
3. Choke stove tube clogged.	3. Clean tube.
4. Choke unloader adjustment incorrect.	4. Correct unloader adjustment.
5. Choke plate shaft or linkage binding.	5. Clean and align.
6. Engine warmup too slow.	6. Check cooling system.
7. Clogged exhaust crossover passage.	7. Clean crossover passage.
8. Choke clean air tube clogged.	8. Clean tube.
9. Choke vacuum piston inoperative.	9. Clean and open line.
10. Owner fails to depress accelerator to allow choke plate to close.	10. Instruct owner.
11. Air cleaner or cleaner gasket binds choke plate to close.	11. Install cleaner and gasket correctly.
12. Faulty thermostatic spring.	12. Replace spring.
13. Choke assembled improperly.	13. Assemble correctly.
14. Defective cold start valve.	14. Replace valve.
15. Loose choke linkage.	15. Adjust and secure.
16. Electric assist defective.	16. Replace.

PROBLEM: STALLING AND/OR ROUGH IDLING

Possible Cause	Correction
1. Idle speed too slow.	1. Increase idle speed.
2. Fast idle speed too slow.	2. Increase fast idle speed.
3. Throttle return dashpot inoperative.	3. Replace dashpot.
4. Throttle dashpot improperly adjusted.	4. Adjust dashpot correctly.
5. Fuel level too high.	5. Lower fuel level.
6. Fuel level too low.	6. Raise fuel level.
7. Idle mixture screw or screws improperly adjusted.	7. Adjust mixture screws.
8. Idle system clogged.	8. Clean carburetor.
9. Choke set too rich.	9. Lean choke setting.
10. Choke set too lean.	10. Richen choke setting.
11. Carburetor flooding.	11. (See carburetor flooding.)
12. Clogged air cleaner.	12. Clean or replace air cleaner.
13. Vacuum leak.	13. Repair leak.
14. Ruptured vacuum power jet diaphragm.	14. Replace diaphragm.
15. Idle mixture needles grooved.	15. Replace needles (screws).
16. Carburetor icing.	16. Warm up and take corrective action.
17. PCV system clogged.	17. Clean PCV system.
18. Hot idle compensator (air valve) inoperative.	18. Replace air valve.
19. Bowl vent clogged.	19. Open vent.
20. Idle air bleeds clogged.	20. Clean carburetor.
21. Choke valve binding.	21. Repair.
22. Choke linkage sticking.	22. Free linkage.
23. Defective choke coil.	23. Replace coil.
24. Vacuum diaphragm for choke opening incorrectly adjusted.	24. Adjust to specs.
25. Defective float needle valve.	25. Replace needle valve.
26. Exhaust heat valve stuck open.	26. Free heat valve or replace.
27. Incorrect distributor vacuum advance.	27. Adjust to specs.
28. Inoperative canister purge valve.	28. Replace valve or canister.
29. Restricted air cleaner and/or exhaust.	29. Repair or replace.
30. Secondary throttle sticking open.	30. Free throttle.
31. Fast idle solenoid inoperative.	31. Replace solenoid.
32. Defective glow plug system.	32. Repair system.
33. Injection pump timing off.	33. Correct timing.
34. Air in injection lines.	34. Bleed off air.
35. Low compression.	35. Determine reason and repair.
36. Faulty injection pump.	36. Repair or replace pump.
37. Malfunctioning injection nozzle(s).	37. Repair or replace nozzle(s).
38. Contaminated fuel.	38. Flush system. Add fresh, clean fuel.
39. EGR vacuum hoses misrouted.	39. Correct as required.
40. Defective EGR valve.	40. Replace valve.

PROBLEM: IDLE SPEED VARIES

Possible Cause	Correction
1. Defective or improperly adjusted throttle return dashpot.	1. Replace or adjust dashpot.
2. Loose or defective power valve.	2. Tighten or replace power valve.
3. Throttle linkage dirty.	3. Clean linkage.
4. Throttle return spring weak.	4. Replace with stronger spring.
5. Accelerator pedal sticking.	5. Clean and lubricate.
6. PCV valve sticking.	6. Clean valve.
7. Fuel inlet valve sticking.	7. Clean or replace valve.
8. Loose or inoperative spark control.	8. Tighten or replace valve.
9. Fast idle cam sticking.	9. Free cam linkage.
10. Defective air cleaner vacuum motor.	10. Replace motor.
11. Dirty or malfunctioning fuel injectors.	11. Clean or replace.
12. Malfunctioning injector control.	12. Replace control.

PROBLEM: POOR ACCELERATION

Possible Cause	Correction
1. Accelerator pump linkage disconnected.	1. Connect linkage.
2. Accelerator pump linkage improperly adjusted.	2. Adjust correctly.
3. Accelerator pump diaphragm ruptured.	3. Replace diaphragm.
4. Accelerator pump piston worn or cracked.	4. Replace piston.
5. Accelerator pump check valve dirty or defective.	5. Clean or replace check valve.
6. Accelerating jets clogged.	6. Clean jets.

Problem: Poor Acceleration continued

	Possible Cause	Correction
7.	Fuel level too low.	Raise level.
8.	Accelerator pump follow through spring too weak.	Replace spring.
9.	Exhaust manifold heat control valve stuck.	Free heat control valve.
10.	Power valve inoperative.	Clean or replace power valve.
11.	Low pump pressure.	Replace pump.
12.	Main fuel passage clogged.	Clean carburetor.
13.	Air leaks.	Repair leaks.
14.	Defective secondary diaphragm.	Replace diaphragm.
15.	Secondary throttle plates stuck.	Free plates.
16.	Clogged air cleaner.	Clean or replace.
17.	Faulty fuel injectors.	Clean, adjust, or replace.
18.	Fuel injection control computer defective.	Replace.
19.	Plugged catalytic converter.	Replace converter.
20.	Clogged muffler.	Replace muffler.
21.	Bent tail pipe.	Replace tail pipe.
22.	Clogged fuel filters.	Clean or replace filters.
23.	Defective injection pump.	Rebuild or replace pump.
24.	Defective injection nozzles.	Replace nozzles.

PROBLEM: LEAN MIXTURE AT CRUISING SPEEDS

	Possible Cause	Correction
1.	Low float setting.	Raise float setting.
2.	Low fuel volume or pressure.	(See insufficient fuel delivery.)
3.	Bowl vent clogged.	Clean vent.
4.	Main discharge jet too small.	Install proper jet.
5.	Metering rod or valve inoperative.	Repair rod or valve.
6.	Air leaks.	Repair leaks.
7.	Exhaust heat control stuck.	Free control valve.
8.	Vacuum passage to distributor clogged.	Clean carburetor.
9.	Defective spark valve.	Tighten or replace spark valve.
10.	Main discharge jet clogged.	Clean carburetor.
11.	Incorrect carburetor jet size.	Replace jet with correct size.
12.	Defective injection pump.	Replace pump.
13.	Fuel injection system control malfunction.	Adjust, repair, or replace.
14.	Dirty or defective injector nozzles.	Clean or replace nozzles.

PROBLEM: RICH MIXTURE AT CRUISING SPEEDS

	Possible Cause	Correction
1.	Air cleaner clogged.	Clean or replace cleaner.
2.	Leaking float.	Repair float.
3.	Float level too high.	Adjust float level.
4.	Float inlet valve dirty.	Clean valve and lines.
5.	Excessive fuel pressure.	Reduce fuel pressure.
6.	Fuel flow pulsations.	Install pulsation damper.
7.	Main discharge jet too large.	Install correct size jet.
8.	Choke on.	Free and adjust choke.
9.	Engine running too cold.	Check cooling system.
10.	Power valve diaphragm ruptured.	Replace valve.
11.	Air bleeds clogged.	Clean carburetor.
12.	Faulty fuel injection pump.	Clean, adjust, or replace pump.
13.	Malfunctioning fuel injection control system.	Adjust, repair, or replace affected parts.

PROBLEM: TOP SPEED LOWERED

	Possible Cause	Correction
1.	Incorrect throttle linkage adjustment.	Adjust linkage correctly.
2.	Clogged air cleaner.	Clean or replace air cleaner.
3	Choke on.	Clean and adjust choke.
4.	Low or high float level.	Adjust float level.
5.	Fuel pressure too low or high.	Adjust fuel pressure.
6.	Air leak.	Repair leak.

Problem: Top Speed Lowered continued

Possible Cause	Correction
7. Secondary throttle valves inoperative.	7. Clean and rebuild carburetor.
8. Improper secondary throttle adjustment.	8. Adjust throttle correctly.
9. Main jet too small.	9. Install proper jet.
10. Main jet clogged.	10. Clean carburetor.
11. Obstruction (dirt, mat, etc.) under accelerator pedal.	11. Remove obstruction.
12. Engine operating too cold or hot.	12. Check cooling system.
13. Clogged catalytic converter.	13. Repair or replace converter.
14. Pinched exhaust pipe.	14. Replace pipe.
15. Clogged muffler.	15. Replace muffler.
16. Faulty injection pump.	16. Adjust, repair, or replace pump.
17. Plugged injection nozzles.	17. Clean or replace nozzles.
18. Fuel injection system control malfunction.	18. Repair, adjust, or replace affected unit(s).
19. Low compression.	19. Repair engine.
20. Incorrect (small) tire size.	20. Install correct size tires.
21. Incorrect final drive ratio.	21. Install correct gears.

PROBLEM: HARD STARTING — COLD

Possible Cause	Correction
1. Choke inoperative or improperly adjusted.	1. Clean and adjust choke.
2. Flooding from excessive use of accelerator pump or rich choke.	2. Hold throttle in wide open position and crank engine. Instruct owner as to proper starting technique.
3. Failure to depress throttle to allow choke valve to close.	3. Instruct owner.
4. Air leak.	4. Repair leak.
5. Clogged air cleaner.	5. Clean or replace cleaner.
6. Fuel level incorrect.	6. Adjust fuel level.
7. Bowl vent clogged.	7. Clean vent.
8. No fuel delivery.	8. Check tank and delivery system.
9. Stale or contaminated fuel.	9. Drain tank. Flush system. Fill with fresh fuel.
10. Gasoline not sufficiently volatile.	10. Change to more volatile fuel.
11. Incorrect grade of diesel fuel.	11. Use correct grade fuel.
12. Vacuum leaks.	12. Locate and repair.
13. Defective ignition components (plugs, points, etc.).	13. Locate, clean, adjust, and repair.
14. Incorrect timing.	14. Set to specifications.
15. Discharged or defective battery.	15. Charge or replace battery.
16. Corroded or loose battery and starter connections.	16. Clean and tighten connections.
17. Defective starter motor.	17. Rebuild or replace starter.

PROBLEM: HARD STARTING — HOT

Possible Cause	Correction
1. Flooding from excessive use of choke or accelerator pump.	1. Hold throttle wide open and crank until engine starts.
2. Vapor lock.	2. Cool lines. Change to less volatile fuel and protect lines from heat.
3. Bowl vent clogged.	3. Clean vent.
4. Air leak.	4. Repair leak.
5. Clogged air cleaner.	5. Clean or replace cleaner.
6. Fuel level incorrect.	6. Adjust fuel level.
7. No fuel delivery.	7. Check delivery system.
8. Stale or contaminated fuel.	8. Drain tank and carburetor. Fill with fresh fuel.
9. Overheated engine.	9. Check cooling system.
10. Exhaust heat control valve stuck.	10. Free control valve.
11. High elevation.	11. Change to less volatile fuel.
12. Improper choke unloader adjustment.	12. Adjust properly.
13. Vacuum hoses split, kinked, or loose.	13. Replace. Secure connections.
14. Incorrect ignition timing.	14. Set to specifications.
15. Fuel vapor "boil over."	15. Hold throttle full open while cranking.
16. Overheated carburetor.	16. Check for proper heat shield and/or insulator installation.
17. Malfunctioning fuel injection system control.	17. Repair, adjust, or replace affected parts.

PROBLEM: FUEL PUMP NOISE

Possible Cause	Correction
1. Pump-to-block fasteners loose.	1. Tighten fasteners.
2. Rocker arm or eccentric worn.	2. Replace.
3. Rocker arm spring weak or broken.	3. Replace rocker arm spring.

Problem: Fuel Pump Noise continued

Possible Cause	Correction
4. Electric pump loose on mounting.	4. Tighten pump fasteners.
5. Electric pump body touching metal panel, line, etc.	5. Bend panel, line, etc., to provide proper clearance.
6. Defective electric pump.	6. Replace pump.
7. Loose line to electric pump.	7. Secure line.

PROBLEM: FUEL TANK AND INLET LINE COLLAPSE

Possible Cause	Correction
1. Clogged tank vent.	1. Open vent.
2. Clogged tank filter.	2. Clean or replace.
3. Pinched line.	3. Repair.

PROBLEM: EXCESSIVE FUEL CONSUMPTION

Possible Cause	Correction
1. Excessive speed.	1. Caution owner to reduce speed.
2. Rapid acceleration.	2. Accelerate moderately.
3. Heavy loads (trailer, luggage, etc.).	3. Normal.
4. Low tire pressure.	4. Inflate tires to proper level.
5. Dragging brakes.	5. Loosen brakes.
6. Stop and start driving.	6. Normal.
7. Fuel leaks (external).	7. Repair leaks.
8. Clogged air cleaner.	8. Clean or replace cleaner.
9. Choke on.	9. Clean and adjust choke.
10. Main jets too large.	10. Reduce jet size.
11. Accelerator pump stroke adjusted wrong.	11. Change pump stroke adjustment.
12. Low grade or stale gasoline.	12. Use higher grade fuel. Use fresh fuel.
13. Exhaust heat control valve stuck.	13. Free valve.
14. Fuel level too high.	14. Lower fuel level.
15. Leaking float.	15. Repair float.
16. Faulty inlet valve or seat.	16. Replace both valve and seat.
17. Metering rod worn.	17. Replace rod.
18. Fuel pressure excessive.	18. Lower pressure.
19. Power valve stuck ON.	19. Replace power valve.
20. Heavy fuel pulsations.	20. Install pulsation damper.
21. Front wheel alignment out.	21. Align front wheels.
22. Exhaust system clogged.	22. Replace muffler and tail pipe.
23. Transmission slipping.	23. Adjust transmission.
24. Wrong axle gear ratio.	24. Change to different ratio.
25. Incorrect tire size.	25. Install proper size tires.
26. Malfunctioning fuel injection system control.	26. Repair, adjust, or replace affected control.
27. Faulty fuel injector pump.	27. Repair, adjust, or replace pump.
28. Injector pump timing incorrect.	28. Set to specifications.
29. Incorrect grade of diesel fuel.	29. Use correct grade.
30. Torque converter lockout inoperative.	30. Repair or replace lockout and/or control unit.

IGNITION SYSTEM PROBLEM DIAGNOSIS

PROBLEM: NO SPARK AT PLUGS

Possible Cause	Correction
1. Breaker points oily, dirty, or burned.	1. Install new points.
2. Breaker points not opening.	2. Adjust point gap.
3. Defective condenser.	3. Replace condenser.
4. Discharged battery.	4. Charge battery.
5. Faulty coil or primary circuit resistor.	5. Replace coil or resistor.
6. No primary current to points.	6. Check ignition switch, coil, resistor, wiring.
7. Defective coil high tension lead.	7. Replace lead.
8. Defective rotor and/or distributor cap.	8. Replace cap and rotor.
9. Defective plug wires.	9. Replace wire.
10. Moisture in distributor cap and on points.	10. Dry cap and points.
11. Breaker plate not grounded.	11. Replace or tighten ground wire.
12. Defective ignition control unit.	12. Replace control unit.
13. Loose, corroded, or open electronic control unit ground lead.	13. Tighten, clean, or connect as needed.
14. Loose, corroded, or disconnected primary connections to distributor.	14. Clean, cover with special, protective grease and shove firmly together.
15. Defective distributor electronic pickup.	15. Replace pickup unit.
16. Trigger wheel positioned too high.	16. Position correctly.
17. Incorrect trigger wheel-to-pickup air gap.	17. Set correctly. Use nonmagnetic feeler gauge.

PROBLEM: WEAK OR INTERMITTENT SPARK AT PLUGS

Possible Cause	Corrections
1. Breaker points oily, dirty, or burned.	1. Install new points.
2. Defective condenser.	2. Install new condenser.
3. Incorrectly set point dwell.	3. Set dwell correctly.
4. Discharged battery.	4. Charge battery.
5. Loose or dirty primary wiring connections.	5. Clean and tighten connections.
6. Weak coil.	6. Replace coil.
7. Defective primary circuit resistor.	7. Replace resistor.
8. Burned rotor and cap contacts.	8. Replace cap and rotor.
9. Defective resistance spark plug wires.	9. Install correct resistance wires.
10. Insufficient system voltage.	10. Adjust regulator.
11. Weak breaker spring pressure.	11. Increase spring pressure.
12. Worn distributor bushings or bent shaft.	12. Replace bushings or shaft.
13. Worn distributor cam.	13. Replace cam.
14. Breaker arm sticking.	14. Free and lubricate bushing.
15. Loose spark plug wires.	15. Clean and tighten connections.
16. Defective distributor electronic pickup.	16. Replace pickup.
17. Trigger wheel pin sheared.	17. Replace pin.
18. Shorting primary wiring.	18. Replace wire and relocate.
19. Loose wiring harness connectors.	19. Tighten connections.

PROBLEM: MISSING AT IDLE OR LOW SPEED

Possible Cause	Correction
1. Weak or intermittent spark at plugs.	1. (See weak or intermittent spark at plugs.)
2. Fouled spark plugs.	2. Clean or replace plugs.
3. Spark plug gaps too narrow.	3. Adjust gaps to specs.
4. Improper plug heat range.	4. Install proper heat range.
5. Damaged plugs.	5. Replace plug or plugs.
6. Defective distributor electronic pickup.	6. Replace pickup unit.
7. Loose harness connections.	7. Clean and tighten connections.
8. Discharged battery.	8. Charge or replace battery.
9. Coil polarity incorrect.	9. Reverse coil primary leads.

PROBLEM: MISSING DURING ACCELERATION

Possible Cause	Correction
1. Weak spark.	1. (See weak or intermittent spark at plugs.)
2. Plugs damp.	2. Dry plugs.
3. Fouled plugs.	3. Clean or replace plugs.
4. Plug gap too wide.	4. Gap as specified.
5. Damaged plug.	5. Replace plug.
6. Incorrect trigger wheel-to-pickup air gap.	6. Set gap to specifications.
7. Defective vacuum advance.	7. Repair or replace vacuum advance.
8. Incorrect coil polarity.	8. Reverse coil primary leads.
9. Cross-firing.	9. Rearrange ignition secondary wires.

PROBLEM: MISSING DURING CRUISING AND HIGH SPEED OPERATION

Possible Cause	Correction
1. Weak spark.	1. (See weak or intermittent spark at plugs.)
2. Improper heat range plug (too hot).	2. Install proper heat range plug.
3. Cross-firing.	3. Arrange wires properly. If needed, install new wires.
4. Fouled plug.	4. Clean or replace plugs.
5. Plug gap incorrect.	5. Gap to specs.
6. Damaged plug.	6. Replace plug.
7. Ignition timing incorrect.	7. Time correctly.
8. Defective distributor.	8. Repair or replace distributor.
9. Loose or corroded wire connections.	9. Clean and tighten connections.
10. Defective spark plug wires.	10. Replace wires.

PROBLEM: MISSING AT ALL SPEEDS

Possible Cause	Correction
1. Weak spark.	1. (See weak or intermittent spark at plugs.)
2. Fouled spark plugs.	2. Clean or replace plugs.
3. Damaged plug.	3. Replace plugs.
4. Cross-firing.	4. Arrange wiring correctly and if needed, install new wires.
5. Plug gap too wide or too narrow.	5. Adjust gap as needed.
6. Plugs and/or distributor damp.	6. Dry distributor and plugs.
7. Improper plug heat range.	7. Change to correct heat range.
8. Defective distributor.	8. Repair or replace distributor.
9. Defective spark plug wires.	9. Replace plug wires.
10. Distributor trigger wheel pin sheared or missing.	10. Install new pin.
11. Cross-firing.	11. Arrange plug wires as specified.
12. Burned or corroded breaker points.	12. Replace and gap points.
13. Defective condenser.	13. Replace condenser.

PROBLEM: SHORT POINT LIFE

Possible Cause	Correction
1. Oil on points.	1. Clean and remove source of oil.
2. Excessive system voltage.	2. Adjust voltage regulator.
3. Primary ballast resistor bypassed.	3. Run coil circuit through resistor.
4. Incorrect primary circuit ballast resistor.	4. Install correct resistor.
5. Defective condenser.	5. Install new condenser.
6. Incorrect capacity condenser.	6. Install condenser of correct capacity.
7. Dirt on points.	7. Clean points.
8. Defective coil.	8. Replace coil.
9. Worn distributor shaft or bushings.	9. Rebuild or replace distributor.
10. Defective ignition switch.	10. Replace switch.
11. Points improperly aligned.	11. Align points.
12. Points improperly gapped.	12. Gap points as specified.

PROBLEM: COIL FAILURE

Possible Cause	Correction
1. Carbon tracking on tower.	1. Replace coil and wire nipple.
2. Excessive system voltage.	2. Adjust voltage regulator.
3. Oil leak in coil.	3. Replace coil.
4. Engine heat damage.	4. Replace coil. Relocate or baffle against heat.
5. Mechanical damage.	5. Replace coil.

PROBLEM: CONDENSER FAILURE

Possible Cause	Correction
1. Moisture damage.	1. Replace condenser.
2. Mechanical damage.	2. Replace condenser.

PROBLEM: SHORT SPARK PLUG LIFE

Possible Cause	Correction
1. Incorrect plug heat range (too hot - burns).	1. Install correct (cooler) heat range.
2. Incorrect plug heat range (too cold - fouls).	2. Install correct (hotter) heat range.
3. Mechanical damage during installation.	3. Install correctly.
4. Loose plug (overheats and burns).	4. Torque plugs.
5. Incorrect reach (too short - fouls).	5. Install plugs with correct reach.
6. Incorrect reach (too long - strikes piston).	6. Install plugs with correct reach.
7. Worn engine - oil fouling.	7. Switch to hotter plugs or overhaul engine.
8. Excessive use of sand blaster.	8. Use blast cleaner properly.
9. Bending center electrode.	9. Bend side electrode only.
10. Detonation.	10. Adjust timing. Change to higher octane gas and/or remove carbon buildup, etc.
11. Preignition.	11. Remove carbon buildup, install valves with full margin, install cooler plugs, etc.
12. Lean mixture.	12. Adjust fuel-air ratio.

PROBLEM: PREIGNITION

Possible Cause	Correction
1. Overheated engine.	1. Check cooling system.
2. Glowing pieces of carbon.	2. Remove carbon.
3. Spark plugs overheating.	3. Change to cooler plugs.
4. Sharp valve edges.	4. Install valves with full margin.
5. Glowing exhaust valve.	5. Check for proper tappet clearance, for sticking, air leaks, etc.

PROBLEM: DETONATION

Possible Cause	Correction
1. Ignition timing advanced.	1. Retard timing.
2. Engine temperature too high.	2. Check cooling system.
3. Carbon buildup is raising compression ratio.	3. Remove carbon.
4. Low octane fuel.	4. Switch to high octane fuel.
5. Exhaust heat control valve stuck.	5. Free valve.
6. Excessive block or head metal removed to increase compression or to true up a warped head or block surface.	6. Use thicker gasket or change head.

PROBLEM: BACKFIRING IN INTAKE MANIFOLD

Possible Cause	Correction
1. Intake valve not properly seating.	1. Check for broken spring, for valve tappet clearance, for sticking, and for seat condition.
2. Lean mixture.	2. Adjust mixture.
3. Cross-firing.	3. Arrange plug wires or install new wires if needed.
4. Plug wires installed wrong.	4. Connect wires to proper plugs.
5. Carbon tracking in distributor cap.	5. Replace cap and rotor.
6. Insufficient choke when engine is cold.	6. Adjust choke.
7. Incorrect ignition timing.	7. Set timing to specifications.

PROBLEM: BACKFIRING IN EXHAUST SYSTEM

Possible Cause	Correction
1. Turning key off and on while car is in motion.	1. Avoid this practice.
2. Current flow interruption in primary circuit.	2. Check circuit for loose connections and shorts.
3. Coil-to-distributor cap secondary wire shorting or coil itself shorting.	3. Check wire and coil.
4. Faulty points or condenser.	4. Replace points and condenser.
5. Weak or intermittent spark at plugs.	5. (See weak or intermittent spark at plugs.)
6. Incorrect valve timing.	6. Correct timing.
7. Air injection system anti-backfire or diverter valve inoperative.	7. Replace valve.

PROBLEM: ENGINE KICKS (TRYS TO RUN BACKWARD) DURING CRANKING

Possible Cause	Correction
1. Ignition timing too far advanced.	1. Retard ignition timing.
2. Plug wires installed incorrectly.	2. Attach wires to proper plugs.
3. Carbon tracking.	3. Replace distributor cap and rotor.

CHARGING SYSTEM PROBLEM DIAGNOSIS

PROBLEM: NO CHARGE (AC GENERATOR OR ALTERNATOR)

Possible Cause	Correction
1. Drive belt loose or broken.	1. Tighten or replace belt.
2. Voltage regulator fusible wire blown.	2. Install new fusible wire.
3. Sticking or worn brushes.	3. Free or replace brushes.
4. Loose or corroded connection.	4. Clean and solder.
5. Rectifiers open.	5. Correct cause. Install new rectifiers.

Problem: No Charge (AC Generator or Alternator) continued

Possible Cause	Correction
6. Charging circuit open.	6. Correct as needed.
7. Open circuit in stator winding.	7. Test. Install new stator as required.
8. Field circuit open.	8. Test and correct as required.
9. Defective field relay.	9. Replace relay.
10. Defective regulator.	10. Replace regulator.
11. Open isolation diode.	11. Replace diode.
12. Open resistor wire.	12. Replace.
13. Drive pulley slipping.	13. Install new key and tighten.
14. Brushes oil soaked.	14. Replace brushes.
15. Corroded or loose brush connections.	15. Clean and tighten connections.
16. "Frozen" (seized) bearing(s).	16. Replace bearing(s). Check shaft for damage.

PROBLEM: LOW OR ERRATIC RATE OF CHARGE (ALTERNATOR)

Possible Cause	Correction
1. Loose drive belt.	1. Tighten belt.
2. Open stator. Grounded or shorted turns in stator windings.	2. Test. Install new stator as needed.
3. High resistance - battery terminals.	3. Clean posts and terminals. Tighten.
4. Charging circuit resistance excessive.	4. Test. Remove as required.
5. Engine ground strap loose or broken.	5. Tighten or replace strap.
6. Loose connections.	6. Tighten connections.
7. Voltage regulator points oxidized.	7. Clean and adjust or replace regulator if required.
8. Voltage regulator setting too low.	8. Increase regulator setting.
9. Defective rectifier.	9. Replace rectifier.
10. Dirty, burned slip rings.	10. Turn slip rings.
11. Grounded or shorted turns in rotor.	11. Test. Replace as required.
12. Brushes worn. Brush springs weak.	12. Replace brushes and/or springs.

PROBLEM: EXCESSIVE RATE OF CHARGE (ALTERNATOR)

Possible Cause	Correction
1. Voltage regulator setting too high.	1. Lower regulator setting.
2. Voltage regulator ground defective.	2. Ground properly.
3. Defective voltage regulator.	3. Replace regulator.
4. Alternator field grounded.	4. Repair ground.
5. Open rectifier.	5. Replace rectifier.
6. Loose connections.	6. Tighten connections.

PROBLEM: NOISE (ALTERNATOR)

Possible Cause	Correction
1. Drive belt slipping.	1. Tighten belt.
2. Drive pulley loose.	2. Tighten pulley.
3. Drive pulley misaligned.	3. Align pulley.
4. Mounting bolts loose.	4. Tighten mounting bolts.
5. Worn bearings.	5. Replace bearings.
6. Dry bearing.	6. Lubricate or replace as required.
7. Open or shorted rectifier.	7. Replace rectifier.
8. Sprung rotor shaft.	8. Install new rotor.
9. Open or shorted stator winding.	9. Test. Replace stator as needed.
10. Fan dragging.	10. Adjust for fan clearance.
11. Excessive rotor end play.	11. Adjust for correct end play.
12. Out-of-round or rough slip rings.	12. Turn slip rings.
13. Hardened brushes.	13. Replace brushes.

PROBLEM: REGULATOR POINTS OXIDIZED, PITTED OR BURNED (ALTERNATOR REGULATOR)

Possible Cause	Correction
1. Incorrect regulator connections.	1. Replace regulator. Connect properly.
2. Rotor coil windings shorted.	2. Test. Replace rotor as needed.
3. Regulator setting too high.	3. Reduce regulator setting.
4. Poor ground.	4. Correct ground.

Problem: Regulator Points Oxidized, Pitted, or Burned (Alternator Regulator) continued

Possible Cause	Correction
5. Brush leads touching each other.	5. Separate leads.
6. Air gap incorrect.	6. Adjust air gap.
7. Point gap incorrect.	7. Adjust point gap.
8. Oil on points.	8. Clean points. Replace if needed.
9. Filings or other abrasive particles between points.	9. File or sand. Clean thoroughly.
10. Use of emery cloth.	10. NEVER use emery cloth to clean points.

PROBLEM: NO CHARGE (DC GENERATOR)

Possible Cause	Correction
1. Drive belt loose or broken.	1. Tighten belt or replace.
2. Drive pulley slipping.	2. Install new key and tighten.
3. Commutator dirty.	3. Clean commutator.
4. Commutator burned, out-of-round, or scored.	4. Turn commutator.
5. High mica.	5. Turn commutator and undercut mica.
6. Open, shorted, or grounded field circuit.	6. Repair or replace generator.
7. Open, shorted, or grounded armature windings.	7. Replace or rewind armature.
8. Loose or corroded connections at armature or field terminals.	8. Clean and solder.
9. Brushes worn or brush springs weak.	9. Replace brushes and/or springs.
10. Brushes stuck.	10. Free brushes.
11. Brushes oil soaked.	11. Replace brushes.
12. Corroded or loose brush connections.	12. Clean and tighten.
13. Commutator bar-to-winding solder thrown.	13. Solder and check for shorts, opens, and grounds.
14. Regulator cutout inoperative.	14. Clean points, adjust, or replace.
15. External wiring disconnected, loose, or open.	15. Connect or tighten.
16. Frozen (seized) bearing.	16. Replace bearing. Check shaft.
17. Faulty regulator.	17. Replace regulator. Polarize.

PROBLEM: LOW OR ERRATIC RATE OF CHARGE (DC GENERATOR)

Possible Cause	Correction
1. Loose belt.	1. Tighten belt.
2. Voltage regulator setting low.	2. Adjust setting.
3. Current regulator setting low.	3. Adjust setting.
4. Open armature windings.	4. Rewind or replace armature.
5. High resistance at battery terminals.	5. Clean and tighten terminal connections.
6. Loose or corroded connections.	6. Clean and tighten connections.
7. Engine ground strap loose or broken.	7. Tighten or replace.
8. High resistance in the field circuit.	8. Perform resistance tests and correct as needed.
9. Commutator dirty.	9. Clean commutator.
10. Commutator burned or out-of-round.	10. Turn commutator. Undercut mica.
11. High mica.	11. Turn commutator. Undercut mica.
12. Poor brush contact.	12. Free brushes. Replace brushes or springs as required.
13. Regulator points oxidized.	13. Clean and adjust.
14. Brushes worn, brush springs weak.	14. Replace brushes and/or springs.
15. Faulty regulator.	15. Replace regulator.

PROBLEM: NOISE (DC GENERATOR)

Possible Cause	Correction
1. Dragging armature.	1. Replace bearings and/or armature.
2. Dry bearing.	2. Lubricate bearing.
3. Defective bearing.	3. Replace bearing.
4. Belt slipping.	4. Tighten belt.
5. High mica.	5. Turn commutator and undercut mica.
6. Loose pulley.	6. Tighten or replace.
7. Loose field pole shoes.	7. Tighten field pole shoes.
8. Mounting bolts loose.	8. Tighten bolts.
9. Misaligned pulley.	9. Align correctly.
10. Generator fan dragging.	10. Adjust properly.
11. Excessive armature end play.	11. Adjust end play.
12. Rough or out-of-round commutator.	12. Turn commutator.
13. Worn brushes or weak brush springs.	13. Replace brushes and/or springs.
14. Improper brush seating.	14. Seat brushes.

PROBLEM: EXCESSIVE RATE OF CHARGE (DC GENERATOR)

Possible Cause	Correction
1. Field lead grounded.	1. Correct ground.
2. Current regulator setting too high.	2. Lower setting.
3. Voltage regulator setting too high.	3. Lower setting.
4. Faulty regulator.	4. Replace regulator.

PROBLEM: REGULATOR POINTS OXIDIZED, PITTED, OR BURNED (DC GENERATOR REGULATOR)

Possible Cause	Correction
1. Incorrect regulator connections.	1. Replace regulator and connect properly.
2. Shorted field windings.	2. Rewind or replace generator.
3. Radio noise suppression condenser connected to generator FIELD terminal.	3. Disconnect. Attach to ARM terminal.
4. Improper polarizing procedure.	4. Polarize correctly.
5. Failure to polarize.	5. Polarize.
6. Regulator improperly grounded.	6. Ground correctly.
7. Air gap incorrect.	7. Adjust air gap.
8. Point gap incorrect.	8. Adjust point gap.
9. Oil on points.	9. Clean, replace if required.
10. Small filings or abrasive particles between points.	10. Clean thoroughly after filing or sanding.
11. Use of emery cloth.	11. NEVER use emery cloth to clean points.

PROBLEM: UNDERCHARGED BATTERY

Possible Cause	Correction
1. No charge or low charge rate.	1. (See alternator and generator no or low charge.)
2. Excessive use of starter.	2. Tune engine for faster starting.
3. Defective battery.	3. Replace battery.
4. Excessive resistance in charging circuit.	4. Test and remove resistance.
5. Defective generator.	5. Rebuild or replace generator.
6. Defective regulator.	6. Replace regulator.
7. Low regulator setting.	7. Raise regulator setting.
8. Electrical load exceeds generator rating.	8. Reduce load or install higher capacity generator.
9. Electrical leak in system.	9. Test. Remove source of leak.
10. Excessive starter motor draw.	10. Rebuild or replace starter motor.
11. Water level low in battery cells.	11. Bring electrolyte up to proper level.

PROBLEM: OVERCHARGED BATTERY

Possible Cause	Correction
1. Excessive resistance in voltage regulator circuit.	1. Clean and tighten connections.
2. Voltage regulator setting too high.	2. Lower voltage setting.
3. Upper (double-contact) voltage regulator points stuck.	3. Install new regulator.
4. Regulator-alternator ground wire loose or open.	4. Tighten or replace wire.
5. Defective battery.	5. Replace battery.
6. Voltage regulator coil open.	6. Replace regulator.
7. Grounded field lead (DC generator).	7. Insulate.
8. Current regulator setting too high.	8. Reduce current regulator setting.
9. Other defective regulator parts.	9. Replace regulator.

PROBLEM: EXCESSIVE USE OF BATTERY WATER

Possible Cause	Correction
1. Battery case cracked.	1. Replace battery.
2. Voltage regulator setting too high.	2. Lower voltage setting.
3. Current regulator setting too high (DC generator).	3. Lower current setting.
4. Excessive charge rate from other causes.	4. (See excessive rate of charge and overcharged battery.)
5. Subjected to excessive heat.	5. Change battery location or baffle against heat.
6. Battery sealing compound loose.	6. Reseal.

STARTING SYSTEM PROBLEM DIAGNOSIS

PROBLEM: STARTER WILL NOT CRANK ENGINE

Possible Cause	Correction
1. Dead battery.	1. Charge or replace battery.
2. Loose or dirty battery connections.	2. Clean and tighten connections.
3. Defective starter switch.	3. Replace switch.
4. Defective starter solenoid.	4. Replace solenoid.
5. Defective or improperly adjusted neutral safety switch.	5. Replace or adjust switch.
6. Starter terminal post shorted.	6. Replace insulation.
7. Defective starter.	7. Rebuild or replace starter.
8. Engine bearings seized.	8. Grind shaft. Replace bearings.
9. Engine bearings too tight.	9. Install correct bearings.
10. Piston-to-cylinder wall clearance too small.	10. Fit pistons correctly.
11. Water pump frozen.	11. Thaw. Place antifreeze in cooling system.
12. Insufficient ring clearance.	12. Install correct rings.
13. Hydrostatic lock (water in combustion chamber).	13. Remove water. Repair leak.
14. Starter drive pinion jammed into flywheel teeth.	14. Remove starter. Install new pinion and replace starter ring gear if needed.
15. Starter armature seized.	15. Rebuild or replace starter.

PROBLEM: STARTER CRANKS ENGINE SLOWLY

Possible Cause	Correction
1. Low battery state of charge.	1. Charge battery.
2. Loose or dirty battery cable connections.	2. Clean and tighten connections.
3. Battery capacity too small.	3. Install larger capacity battery.
4. Dirty or burned switch contacts.	4. Replace switch.
5. Excessively heavy engine oil.	5. Drain and install lighter oil.
6. Dragging armature - bent shaft.	6. Replace armature.
7. Dragging armature - worn bushing.	7. Replace bushing.
8. Dirty or burned commutator.	8. Turn commutator.
9. Worn brushes.	9. Install new brushes.
10. Weak brush springs.	10. Install new brush springs.
11. Other starter motor defects.	11. Rebuild or install new starter.
12. Engine bearings, pistons, or rings fitted too close.	12. Provide proper clearance.
13. Cold, heavy oil in manual transmission.	13. Hold clutch IN while cranking.
14. Extreme cold weather.	14. Preheat engine prior to cranking.

PROBLEM: STARTER MAKES EXCESSIVE NOISE

Possible Cause	Correction
1. Starter-to-flywheel housing mounting fasteners loose.	1. Tighten mounting fasteners.
2. Dragging armature.	2. Replace armature and/or bushings.
3. Dragging field pole shoes.	3. Tighten pole shoes.
4. Dry bushings.	4. Lubricate bushings.
5. Chipped pinion teeth.	5. Replace pinion.
6. Chipped flywheel ring gear teeth.	6. Replace ring gear.
7. Bent armature shaft.	7. Replace armature.
8. Worn drive unit.	8. Replace starter drive unit.
9. Loose starter through-bolts. Loose end frame cap screws.	9. Tighten.
10. Flywheel ring gear misaligned.	10. Install new ring gear.

PROBLEM: STARTER CRANKS BUT WILL NOT ENGAGE FLYWHEEL RING GEAR

Possible Cause	Correction
1. Broken spring or bolt (Bendix type).	1. Replace spring or bolt.
2. Dirty drive unit.	2. Clean or replace unit.
3. Sheared drive key.	3. Replace drive key.
4. Stripped (sheared) pinion teeth.	4. Replace drive unit.
5. Section of ring gear teeth stripped.	5. Install new ring gear.
6. Defective or dry overrunning clutch drive unit.	6. Replace drive unit.
7. Snapped armature shaft.	7. Replace armature.
8. Broken spring (overrunning clutch type).	8. Replace drive unit.

PROBLEM: STARTER DRIVE PINION RELEASES SLOWLY OR NOT AT ALL

Possible Cause	Correction
1. Dirty Bendix drive sleeve.	1. Clean sleeve.
2. Drive pinion binds on drive sleeve splines (mechanical bind).	2. Replace drive unit.
3. Starter switch defective.	3. Replace starter switch.
4. Dirty pinion sleeve.	4. Clean sleeve.
5. Disengagement linkage (overrunning clutch type) binding.	5. Clean, align, and adjust linkage.
6. Linkage retracting spring weak or broken.	6. Install new spring.
7. Actuating solenoid sticking.	7. Clean solenoid.
8. Centrifugal pinion release pin sticking.	8. Replace drive unit.
9. Insufficient drive pinion to ring gear clearance.	9. Adjust clearance or replace linkage.

ENGINE AND ACCESSORY NOISE IDENTIFICATION

The noises that can be produced by the engine and engine accessory systems are numerous. They range through loud, indistinct, soft, sharp, metallic, and nonmetallic type sounds.

Accurate diagnosis of engine noises takes a great deal of practice and even the veteran mechanic can be puzzled.

Whenever possible, listen to engine noises while attempting to pinpoint the cause. When the engine is torn down, check to see how accurate your diagnosis was.

The use of a good mechanics stethoscope is very helpful in identifying and locating the source of noises.

BE CAREFUL WHEN MAKING A DIAGNOSIS BASED ON SOUNDS. Do not recommend an engine teardown unless you are POSITIVE that the noise is caused by the engine internal parts. Remember that a great number of so-called engine noises are made by the accessory units such as the water pump, fan, EGR valve, alternator, and air conditioning compressor.

ENGINE AND ACCESSORY NOISE DIAGNOSIS

PROBLEM: NOISY VALVE TRAIN

SOUND IDENTIFICATION: Noisy valves may be identified by either a regular or irregular sharp, clicking, or tapping sound. If excessive tappet clearance exists, the clicking will be very regular and the frequency will increase with engine rpm. Sticking valves and faulty lifters will cause intermittent clicking of varying intensity.

Possible Cause	Correction
1. Insufficient lubrication.	1. Provide ample lubrication.
2. Insufficient stem-to-guide clearance.	2. Ream guides to correct size.
3. Warped valve stem.	3. Replace valve.
4. Carboned stem and guide.	4. Clean stem and guide. Replace both if excessive wear is present.
5. Broken valve spring.	5. Replace spring.
6. Weak, corroded, or incorrect spring.	6. Replace with correct spring.
7. Sticking hydraulic lifters.	7. Clean or replace lifters.
8. Improper tappet (valve stem-to-rocker arm) clearance.	8. Set clearance as specified.
9. Valve seat or valve head not concentric with guide or stem.	9. Regrind valve and/or seat.
10. Sticking rocker arm.	10. Provide correct clearance.
11. Cam follower (valve lifter) loose in bore or chipped.	11. Ream for oversize lifter or replace lifter.
12. Valve spring installed with closed end away from head or block.	12. Reverse spring position.
13. Excessively low or high oil level in pan.	13. Bring oil level to correct height.
14. Loose or broken rocker arm.	14. Tighten or replace arm.
15. Loose or broken valve seat.	15. Replace insert and stake as recommended.

PROBLEM: CRANKSHAFT BEARING AND FLYWHEEL KNOCKS

SOUND IDENTIFICATION: Dull, heavy pound or thud - especially noticeable during periods of heavy engine loading. Frequency is related to crankshaft rpm. The loose bearing may generally be isolated by shorting spark plugs. When the plugs in line with the bearing are shorted, the sound will change.

If all the main bearings are quite loose, a great deal more noise will be evident and the frequency will increase.

When excessive end play causes knocking, holding in the clutch will usually alter the sound. To test for a loose flywheel, turn off the key and just before the engine stops, turn the key on again. If the flywheel is loose, a distinct knock will occur when the key is turned on.

Possible Cause	Correction
1. Shaft worn.	1. Regrind or replace shaft.
2. Bearing worn.	2. Replace bearing.
3. Thin oil.	3. Change to correct viscosity.
4. Low oil pressure.	4. Correct as required.
5. Excessive end play.	5. Correct end play.
6. Sprung crankshaft.	6. Straighten or replace crankshaft.
7. Loose flywheel.	7. Tighten flywheel fasteners.

PROBLEM: CONNECTING ROD KNOCK

SOUND IDENTIFICATION: The connecting rod knock is usually more evident when the engine is floating (not accelerating or holding back on compression) at speed around 30 mph (48 km/h).

The knock, a regular light metallic rap, can either be eliminated or greatly subdued by shorting out the cylinder concerned.

Possible Cause	Correction
1. Crankshaft rod journal worn.	1. Grind journal or replace shaft.
2. Connecting rod bearings worn.	2. Install new bearings.
3. Oil diluted.	3. Change to correct viscosity.
4. Low oil pressure.	4. Correct as required.
5. Bent or twisted rod.	5. Straighten rod. Replace insert bearing. Replace rod if bend or twist is excessive.

PROBLEM: PISTON SLAP

SOUND IDENTIFICATION: Piston slap is caused by the piston tipping from side to side in the cylinder. This tipping produces sounds that can range from a regular clicking to a very distinct hollow clatter - depending on the severity of wear.

Piston slap will be more noticeable when the engine is COLD. In mild cases, it may actually disappear after the engine is warmed up. Adding a tablespoon of heavy oil to each cylinder should temporarily quiet the noise. Do not add oil to diesel engine.

Possible Cause	Correction
1. Cylinder worn.	1. Rebore and fit oversize pistons.
2. Pistons badly worn.	2. Rebore and fit oversize pistons.
3. Pistons mildly worn.	3. May be expanded by knurling, peening, etc.
4. Piston pin fitted too tight.	4. Fit pins as specified.
5. Insufficient lubrication.	5. Correct as required.

PROBLEM: LOOSE PISTON PINS

SOUND IDENTIFICATION: Loose pins will cause a sharp, double-knock especially at idle speeds.

If only one pin is loose, when the spark plug in this particular cylinder is shorted, the knocking will become more distinct. If all pins are loose, shorting one plug will not materially alter the sounds.

Possible Cause	Correction
1. Piston pin worn.	1. Fit new pins of correct size.
2. Piston pin hole worn.	2. Fit oversize pin.
3. Connecting rod bushing worn.	3. Replace bushing or fit oversize pin.
4. Insufficient lubrication.	4. Correct as required.
5. Piston pin locks missing.	5. Install locks.
6. Piston pin lock loose.	6. Tighten lock.

PROBLEM: TIMING GEAR, CHAIN, AND BELT NOISE

SOUND IDENTIFICATION: Timing gears, chains, and belts can produce noises varying from a high pitched howl (fitted too tight) to a low level chatter or growl (badly worn). The timing chain or belt can slap against the cover, producing a thumping or scraping sound. A missing chain tooth will cause a regular and distinct knock. A tight belt can also produce a whirring sound.

Possible Cause	Correction
1. Worn chain.	1. Replace chain and sprockets.
2. Worn sprockets.	2. Replace chain and sprockets.
3. Loose gear or sprocket.	3. Replace gear.
4. Excessive end play.	4. Correct as needed.
5. Gear misalignment.	5. Align properly.
6. Worn gear.	6. Replace both camshaft and crankshaft gear.
7. Excessive front camshaft or crankshaft bearing clearance.	7. Correct as required.
8. Gear tooth missing.	8. Replace both gears.
9. Worn belt.	9. Replace belt.
10. Worn or defective belt adjuster.	10. Replace adjuster.

PROBLEM: COMBUSTION KNOCKS

SOUND IDENTIFICATION: When the fuel charge is fired before the spark plug fires (preignition) or when a double-flame front is produced that creates a violent burning of the fuel charge (detonation), a sharp metallic pinging sound is created. This pinging is most noticeable during heavy acceleration.

Possible Cause	Correction
1. Carbon buildup.	1. Remove carbon.
2. Plugs too hot - wrong heat range.	2. Change to cooler plugs.
3. Plugs loose.	3. Torque plugs.
4. Ignition timing advanced too far.	4. Retard timing.
5. Low octane gasoline.	5. Change to higher octane.
6. Overheated valve edge.	6. Install valve with sufficient margin.
7. Lean fuel mixture.	7. Enrichen fuel mixture.

PROBLEM: OTHER ENGINE NOISES

SOUND IDENTIFICATION: The various accessory units such as the water pump, alternator, power steering pump, and air conditioning compressor can produce a variety of squealing, grinding, thumping, and howling noises. They may be quickly checked by disconnecting the accessory drive belts.

Engine mounts can cause heavy metallic noises if they are too tight or too loose.

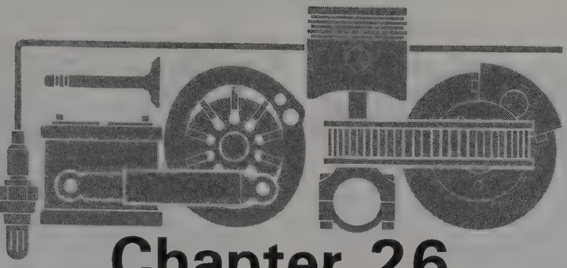
Exhaust pipes, mufflers, and tail pipes can also be responsible for various thumps, clangs, and rattles.

KNOW THESE TERMS

Tune-up, Compression test, Oscilloscope, Exhaust gas analyzer, Cylinder leakage tester, Diagnostic plug-in, Timing light, Dieseling, Vacuum gauge, Cranking vacuum test, Cylinder balance test, Ignition timing, Chassis dynamometer, Computerized diagnostic unit, Compression tester, Shorting harness, Firing order, Stethoscope.

QUIZ - Chapter 25

1. A tune-up involves grinding the valves. True or False?
2. A tune-up should cover the:
   a. Ignition system.
   b. Fuel system.
   c. Charging system.
   d. Cooling system.
   e. All of the systems.
3. A "basic" tune-up, if properly done, will guarantee satisfactory engine performance. True or False?
4. A "comprehensive" tune-up is more effective than a "basic" tune-up. True or False?
5. List 10 important pieces of test equipment used for tune-up work.
6. Specifications for a certain model are good for other years as long as the engine remains basically the same. True or False?
7. Use ______________ replacement parts.
8. Owner comments or answers to questions are often helpful in locating trouble spots. True or False?
9. To assist in an orderly tune-up, avoiding duplication and omission, it is a good idea to use a ______________ ______________.
10. If available, use ______________ ______________ to check on any work or part replacements done prior to the tune-up.
11. The compression test and/or cylinder leakage test are used to determine the __________ __________ of the engine.
12. It is more important for compression readings to be similar in all cylinders than for all cylinders to be up to the specified pressure. True or False?
13. When two adjacent cylinders give similar but low compression readings, a ______________ ______________ could be indicated.
14. Adding oil to the cylinder will raise the compression reading somewhat if the valves are burned. True or False?
15. When taking a compression reading, crank the engine over for at least __________ __________ strokes.
16. Compression pressure above that specified could indicate a buildup of ______________ in the ______________.
17. When using the vacuum gauge, a steady reading is more important than a high one. True or False?
18. Modern engines with high lift cams and more valve overlaps give:
   a. Lower vacuum readings.
   b. Higher vacuum readings.
   c. Lower and somewhat erratic readings.
   d. Higher and steadier readings.
19. Subtract ________ inch of vacuum from vacuum specifications for every __________ feet of elevation above sea level.
20. The cylinder balance test gives a fair indication of engine mechanical condition by operating the engine on __________ cylinders at a time.
21. List 8 important preliminary checks that should be performed before the tune-up is started.
22. The engine should be cold for accurate tune-up work. True or False?
23. Following the tune-up, the car should be ______________ ______________.
24. The ______________ ______________ analyzer is a handy tool to check the carburetion system at all speeds.
25. Where available, a chassis dynamometer is preferable to ______________ ______________ on the streets.
26. When testing compression on a diesel engine, adding a large amount of oil to a cylinder will:
   a. Damage the engine.
   b. Help the engine crank over faster.
   c. Give a more accurate gauge reading.
   d. Produce a low reading.



Chapter 26

CLUTCH SERVICE

After studying this chapter, you will be able to:
- ☐ Explain the construction, operation, and service of diaphragm spring type clutches.
- ☐ Describe the construction, operation, and service of coil spring type clutches.
- ☐ Adjust different types of clutch linkages.
- ☐ Summarize clutch break-in procedures.
- ☐ Diagnose clutch problems and suggest possible corrections.

WARNING! CLUTCH FRICTION MATERIALS CONTAIN ASBESTOS – A KNOWN CARCINOGEN THAT CAN CAUSE CANCER.

GRINDING CLUTCH FRICTION MATERIALS, CLEANING CLUTCH ASSEMBLIES, ETC., CAN PRODUCE SMALL AIRBORNE PARTICLES OF ASBESTOS. THESE ARE EASILY INHALED BY THE MECHANIC. BREATHING THESE ASEBSTOS PARTICLES MAY CAUSE CANCER.

OBSERVE THE FOLLOWING RULES:
1. Never use compressed air to blow clutch assemblies clean. Use a vacuum source or flush with water.
2. When some exposure might be unavoidable, wear an approved filter mask.

BASIC DESIGN AND OPERATION

The modern, single plate, dry disc type clutch uses either individual, direct pressure coil springs, or a diaphragm spring to apply force to the pressure plate.

A direct pressure, coil-spring loaded clutch is illustrated in Fig. 26-1 (see part C). The diaphragm spring type clutch is pictured in Fig. 26-2 (see part B).

DETERMINE REASON FOR CLUTCH FAILURE

Before repairing a damaged clutch, it is a good idea to study the various parts to determine the cause of the failure.

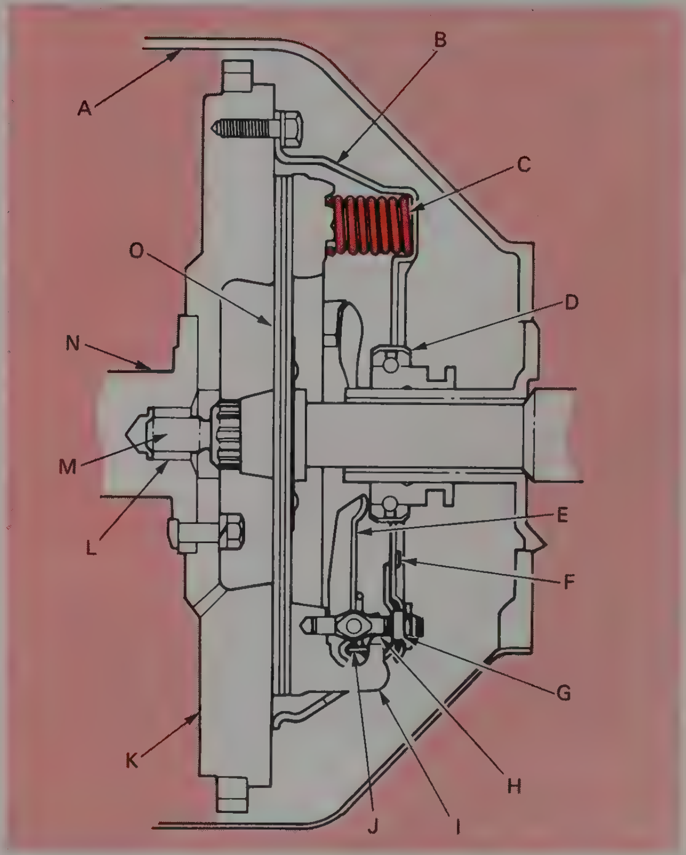


Fig. 26-1. With this clutch, force is applied to pressure plate by coil springs. A—Bell housing. B—Clutch cover. C—Coil spring. D—Clutch release bearing. E—Release lever. F—Anti-rattle spring. G—Adjustment nut. H—Eyebolt. I—Pressure plate. J—Strut. K—Flywheel. L—Pilot bearing. M—Transmission input shaft. N—Crankshaft. O—Drive disc. (Chevrolet)

Merely replacing the worn or damaged parts is an invitation to trouble. Common clutch problems, their causes and cures are covered in the problem diagnosis chart at the end of this chapter.

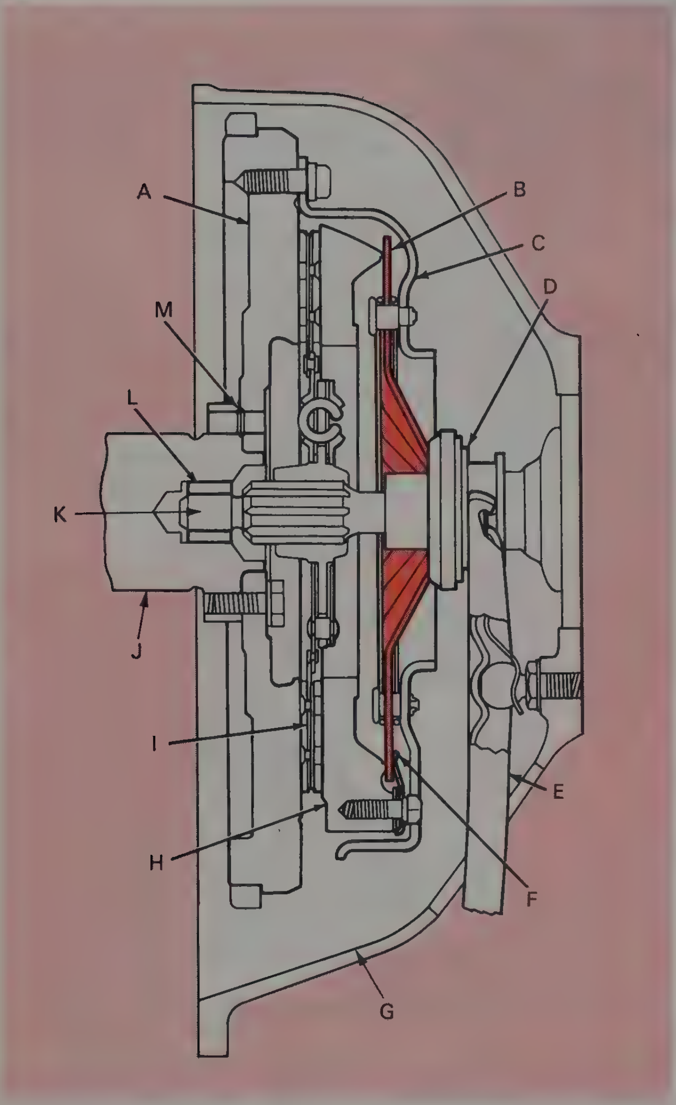


Fig. 26-2. Force is supplied to pressure plate by diaphragm spring. A—Flywheel. B—Diaphragm. C—Clutch cover. D—Clutch release bearing. E—Throw-out fork. F—Retracting spring. G—Bell housing. H—Pressure plate. I—Drive disc. J—Crankshaft. K—Transmission input shaft. L—Pilot bushing. M—Dowel hole. (Chevrolet)

Before condemning the clutch, check for correct pedal "free travel." Inspect the linkage for wear and binding. Check and tighten engine mounts. Tighten rear spring clamp or U-bolt assemblies.

CLUTCH REMOVAL

DISCONNECT BATTERY GROUND STRAP TO PREVENT ENGINE FROM BEING CRANKED WHILE WORKING ON THE CLUTCH.

Drop the drive line (propeller shaft). Using suitable equipment, remove the transmission. Support the weight of the transmission and pull it straight back. See chapter on standard transmissions for complete instructions on removal and installation.

MARK THE CLUTCH COVER AND FLYWHEEL

Use a sharp prick punch to mark both the clutch cover and the flywheel. In the event the same pressure plate-cover assembly is used, it may be installed in exactly the same position. This is necessary so the balance of the flywheel-clutch assembly will not be thrown off. See Fig. 26-3.

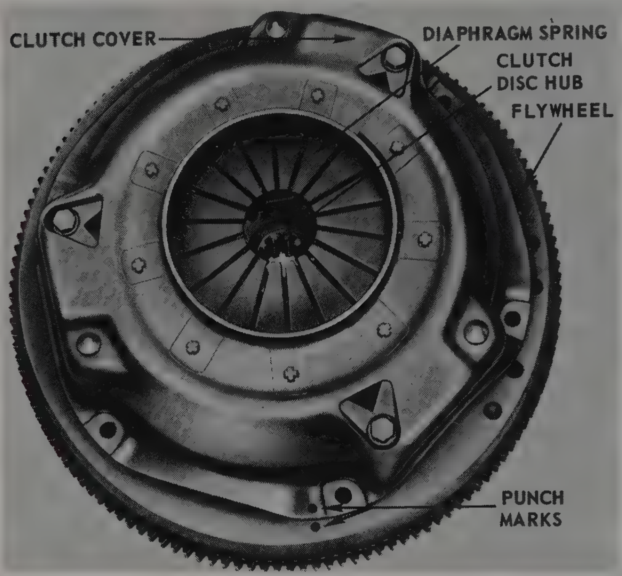


Fig. 26-3. Mark clutch cover and flywheel before removing clutch cover.

LOOSEN CLUTCH COVER FASTENERS A LITTLE AT A TIME

When the transmission has been removed, pull the throw-out bearing out of the throw-out fork. If necessary, to provide working clearance, disconnect the clutch linkage from the fork. The fork may then be tipped back or removed.

In some instances, the clutch assembly can be exposed for removal by dropping a sheet metal splash pan. Other installations require the removal of the entire flywheel housing. Remove only those parts required.

Loosen each clutch cover to flywheel fastener one turn at a time. Continue around the fasteners until all have been loosened. This permits removing the pressure of the coil springs or diaphragm spring evenly. It prevents twisting or warping of the clutch cover.

If desired, a clutch disc aligning arbor may be inserted through the clutch disc hub and into the crankshaft pilot bearing. This will hold the disc in position until the cover fasteners are removed. A used transmission input (clutch) shaft may be used in place of a regular arbor. See Figs. 26-4 and 26-5.

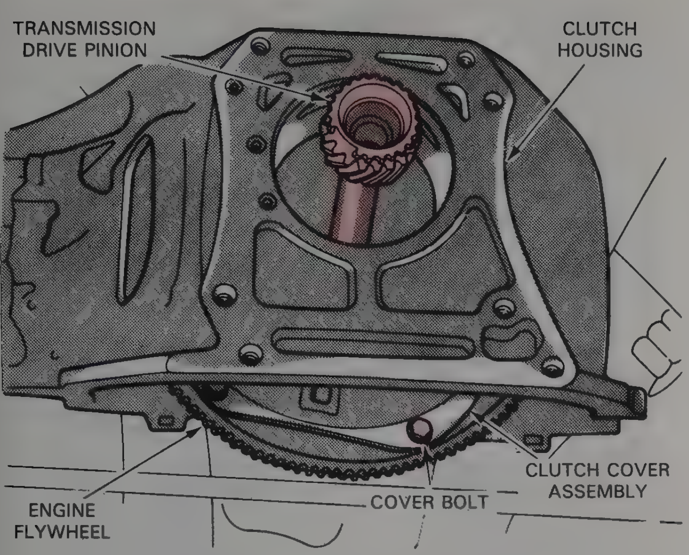

TRANSMISSION DRIVE PINION
CLUTCH HOUSING
CLUTCH COVER ASSEMBLY
COVER BOLT
ENGINE FLYWHEEL

Fig. 26-4. Using transmission input shaft to hold clutch disc in position while removing clutch cover fasteners. The input shaft may also be used to align disc with pilot bearing during cover installation. (Chrysler)

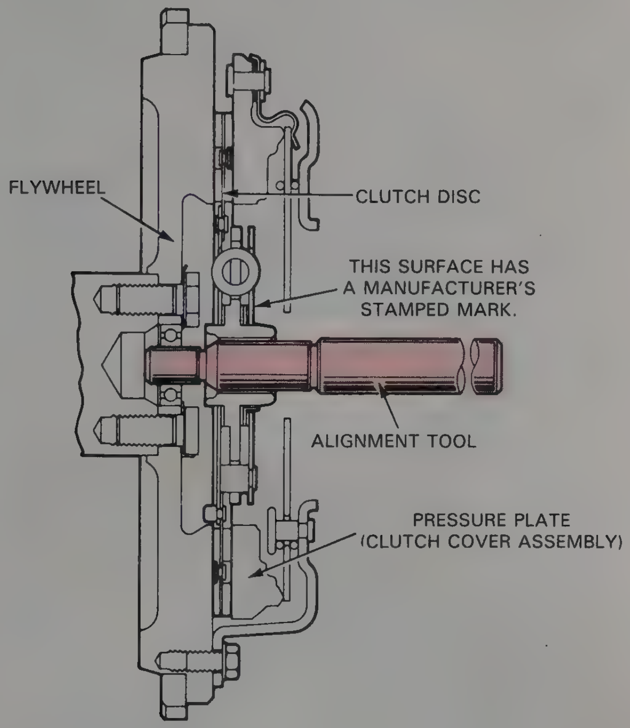

FLYWHEEL
CLUTCH DISC
THIS SURFACE HAS A MANUFACTURER'S STAMPED MARK.
ALIGNMENT TOOL
PRESSURE PLATE (CLUTCH COVER ASSEMBLY)

Fig. 26-5. Cutaway view showing clutch disc being installed and properly aligned with an alignment tool (arbor). (Chrysler)

Remove all but one cover fastener. While holding the clutch cover assembly UP and IN, remove the final fastener. Withdraw the pressure plate and clutch disc. DO NOT TOUCH THE PRESSURE PLATE, CLUTCH DISC, OR FLYWHEEL CLUTCH SURFACE WITH GREASY FINGERS. Refer to Fig. 26-6.

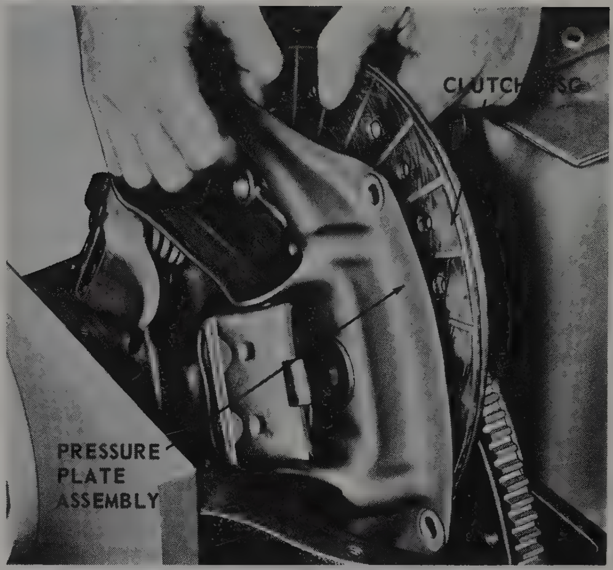

CLUTCH DISC
PRESSURE PLATE ASSEMBLY

Fig. 26-6. Removing clutch disc and pressure plate. (Jeep)

CLEANING PARTS

Clean the flywheel face and pressure plate assembly in a nonpetroleum base cleaner. Both units must be spotlessly clean and absolutely free of the slightest trace of oil or grease. Once cleaned, use care to prevent contamination.

Never wash the throw-out bearing in any kind of solvent. The throw-out bearing is packed with grease and sealed. Washing it would remove or dilute the lubricant. The throw-out bearing may be wiped with a clean cloth moistened with solvent.

SAND CLUTCH FRICTION SURFACES

Use medium-fine emery cloth or equivalent aluminum oxide paper to sand the friction surface of both the flywheel and the pressure plate. Sand so that the sanding scratch marks run across the surface. Sand lightly until the surfaces are covered with fine scratch lines.

This will break the glaze on these surfaces and remove any carboned oil deposits. The new clutch disc will seat smoothly and quickly against the sanded surfaces. See Fig. 26-7.

FLYWHEEL CLUTCH SURFACE

The flywheel clutch friction surface must be clean, dry, lightly sanded, and free of heavy heat checking (cracking). It must also be free of scoring and warpage. Do not expect a clutch disc and pressure plate to work properly when assembled on a glazed, dirty, rough, or warped flywheel surface.

Replace the flywheel or have the friction surface

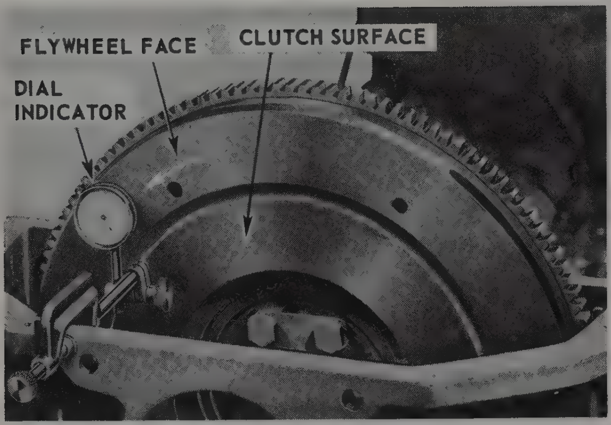

FLYWHEEL FACE
CLUTCH SURFACE
DIAL INDICATOR

Fig. 26-7. Using a dial indicator to check flywheel face for warpage. (Chevrolet)

reground if required. Fig. 26-7 shows the flywheel clutch surface being checked for warpage with a dial indicator.

PRESSURE PLATE ASSEMBLY

Inspect the pressure plate for excessive burning, heat checking, warpage, and for scoring. Check the coils or diaphragm spring for evidence of cracking, loss of temper (overheating), and looseness. Check the ends of the release levers (where they contact throw-out bearing) for wear. In the case of the diaphragm spring, check the ends of the release fingers. See Figs. 26-8 and 26-9.

As with the flywheel, the pressure plate friction surface must be clean, dry, lightly sanded, and free of scoring, warpage, and heavy checking.

Pressure plate assemblies should be rebuilt or replaced unless satisfactory in all respects.

REBUILDING PRESSURE PLATE ASSEMBLY

Many shops use rebuilt or reconditioned pressure plate assemblies in preference to rebuilding the unit in their own shop. Unless proper tools are available and unless the mechanic is thoroughly skilled in clutch rebuilding, it is advisable to use a factory rebuilt unit.

If rebuilding is required, prick punch the pressure plate, clutch cover, and release fingers so that all the parts may be reassembled in the same relative position.

Place the assembly on a special base plate fixture, Fig. 26-10, or set it up in a hydraulic press. When using a hydraulic press, insert spacer blocks under the pressure plate so the clutch cover can move downward when pressure is applied. See Figs. 26-10 and 26-11.

Apply pressure to the clutch cover while loosening the eyebolt adjustment nuts, Fig. 26-11. When the eyebolt nuts have been removed, release the pressure and allow the cover to move upward and off. Fig. 26-12 illustrates a typical coil spring type clutch pressure plate assembly.

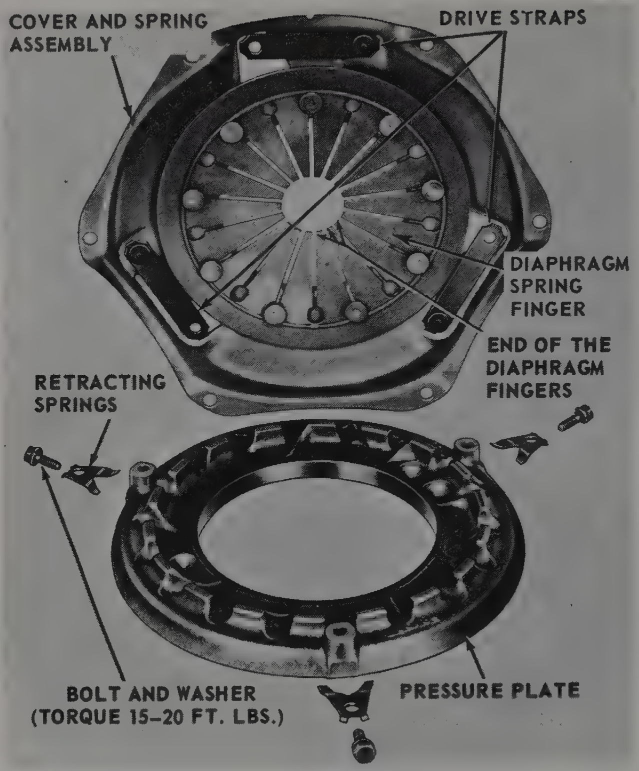

COVER AND SPRING ASSEMBLY
DRIVE STRAPS
DIAPHRAGM SPRING FINGER
END OF THE DIAPHRAGM FINGERS
RETRACTING SPRINGS
BOLT AND WASHER (TORQUE 15-20 FT. LBS.)
PRESSURE PLATE

Fig. 26-8. Pressure plate check points, diaphragm type. (G.M.C.)

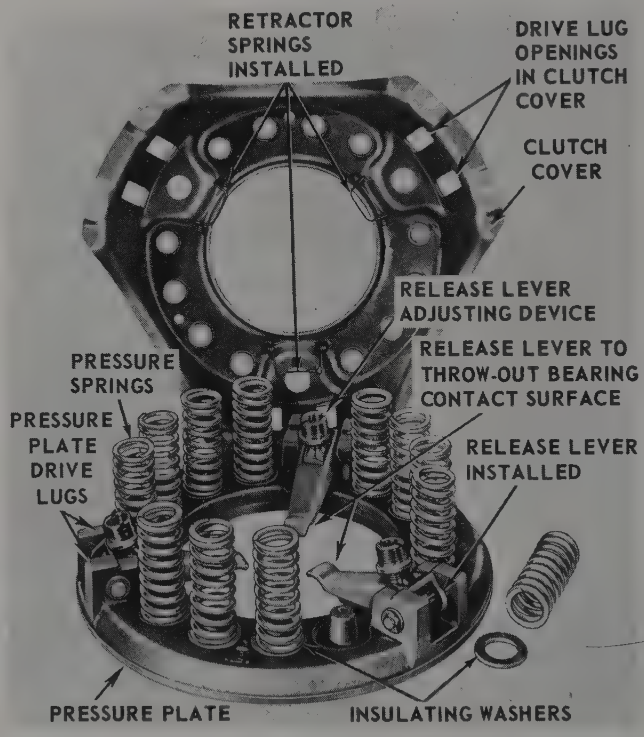

RETRACTOR SPRINGS INSTALLED
DRIVE LUG OPENINGS IN CLUTCH COVER
CLUTCH COVER
RELEASE LEVER ADJUSTING DEVICE
RELEASE LEVER TO THROW-OUT BEARING CONTACT SURFACE
PRESSURE SPRINGS
PRESSURE PLATE DRIVE LUGS
RELEASE LEVER INSTALLED
PRESSURE PLATE
INSULATING WASHERS

Fig. 26-9. Pressure plate check points, coil spring type.

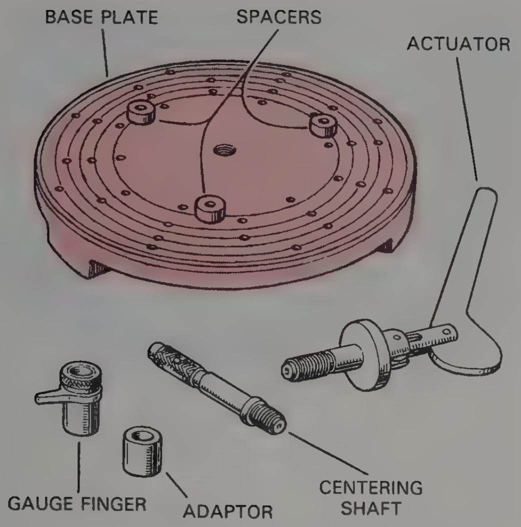

BASE PLATE
SPACERS
ACTUATOR
GAUGE FINGER
ADAPTOR
CENTERING SHAFT

Fig. 26-10. One type of pressure plate servicing fixture features a special base plate.

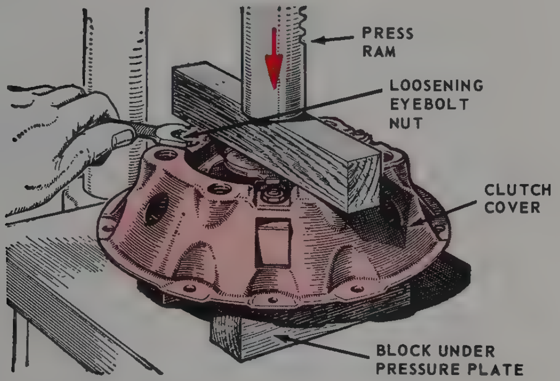

PRESS RAM
LOOSENING EYEBOLT NUT
CLUTCH COVER
BLOCK UNDER PRESSURE PLATE

Fig.26-11. Using a hydraulic press and spacer blocks to disassembly pressure plate assembly.

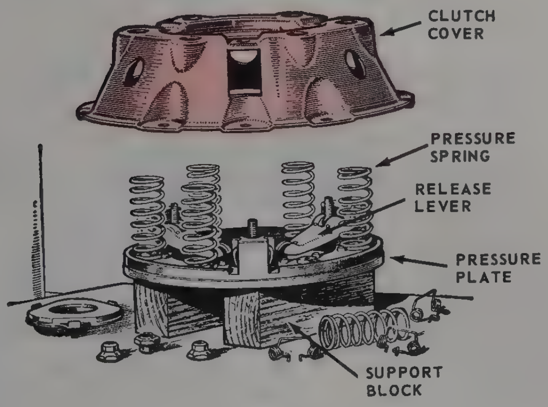

CLUTCH COVER
PRESSURE SPRING
RELEASE LEVER
PRESSURE PLATE
SUPPORT BLOCK

Fig. 26-12. Typical coil spring pressure plate assembly, cover removed.

Check all pressure plate parts for cracking, wear, overheating, and other damage. Check coil spring tension. The pressure plate may be resurfaced if not badly damaged, Fig. 26-13.

Reassemble all the pressure plate parts in their correct order. Align the punch marks. Use new or reconditioned parts as required. Check the clearance between the pressure plate drive lugs and the openings in the clutch cover. Apply lithium (high temperature) grease to the lug-to-cover contact areas. Refer to Fig. 26-14.

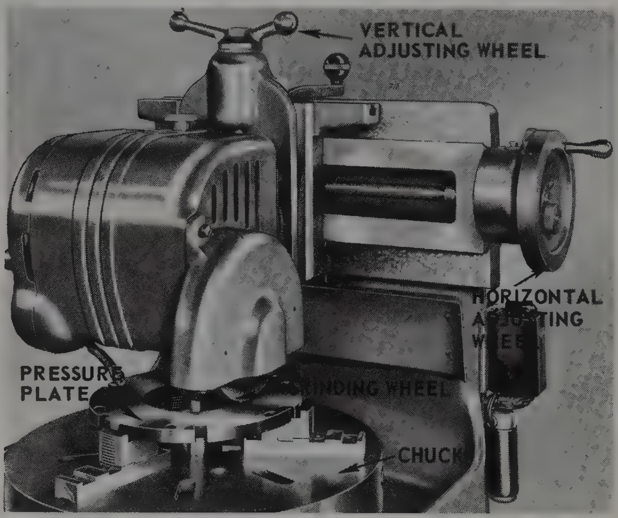

VERTICAL ADJUSTING WHEEL
HORIZONTAL ADJUSTING WHEEL
PRESSURE PLATE
GRINDING WHEEL
CHUCK

Fig. 26-13. Using special grinder to resurface clutch pressure plate. (Van Norman)

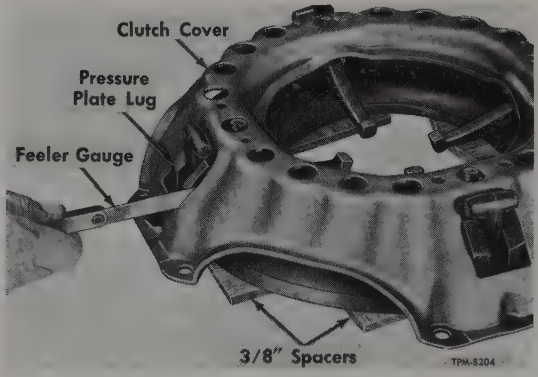

Clutch Cover
Pressure Plate Lug
Feeler Gauge
3/8" Spacers
TPM-8204

Fig. 26-14. Check clearance between pressure plate drive lugs and clutch cover lug openings. Note that coil springs are not in place and that cover is resting on pressure plate. (G.M.C.)

ADJUSTING CLUTCH RELEASE FINGERS

It is important that the pressure plate be withdrawn an equal amount, around the entire circumference, when the release fingers are depressed. This will permit complete disengagement for shifting and smooth engagement for torque transmission.

Mount the assembled pressure plate to either the flywheel or to a special base plate fixture.

Place the specified shims or spacers between the pressure plate and the flywheel. Draw the plate assembly down with the cover fasteners. Tighten each fastener one turn. Continue around until the fasteners are finally tight.

Place a straightedge across the cover and measure the distance from each release finger. Carefully adjust each finger to the specified distance, by tightening or loosening the adjusting nuts. See Fig. 26-15.

Use a press or the clutch fixture to actuate the clutch several times. This will allow the parts to seat. Following actuation, check release finger adjustment for the final time. When adjustment is complete, stake the adjusting nuts so they will not loosen in service. Stake in at least two places.

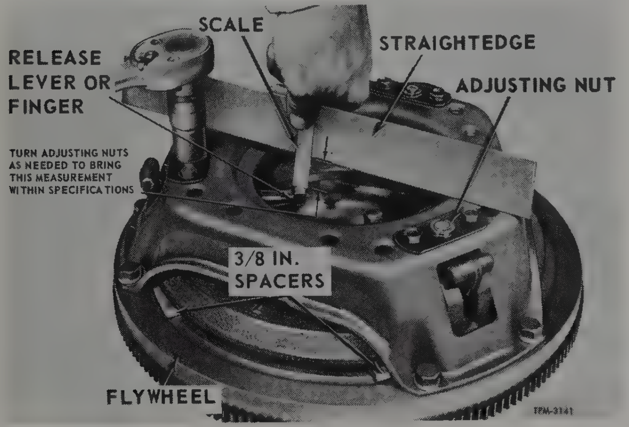


Fig. 26-15. Checking clutch release finger or lever adjustment. Turn lever adjusting nuts as required.

REPLACE CLUTCH PILOT BUSHING

It is good practice to always install a new clutch pilot bushing (or bearing in some cases) when doing a clutch job. Worn pilot bushings can cause clutch chatter, spot burning, and transmission damage. The pilots are relatively inexpensive and are easily changed.

An expandable finger or a threaded puller may be used to pull the pilot bushing, Fig. 26-16. Some bushings are heavily staked. Remove stake marks before pulling. See Fig. 26-34 for pilot BEARING removal and installation.

Clean out the pilot bushing recess in the end of the crankshaft. Wipe the outside of the new pilot with a LIGHT film of high temperature grease. Place the pilot on a driver (chamfered inner hole end facing outward) and drive the bushing into place. Look at Fig. 26-17. When driving a bearing, use a driver that contacts the outer race only. Where retainers are used to secure the bearing or bushing, install as specified.

When installing a pilot bearing, install with the open side of the bearing facing inward.

Apply a thin film of high temperature grease to the inside of the bushing. Never overlubricate the bushing as the excess will find its way onto the clutch disc facing — with disastrous results.

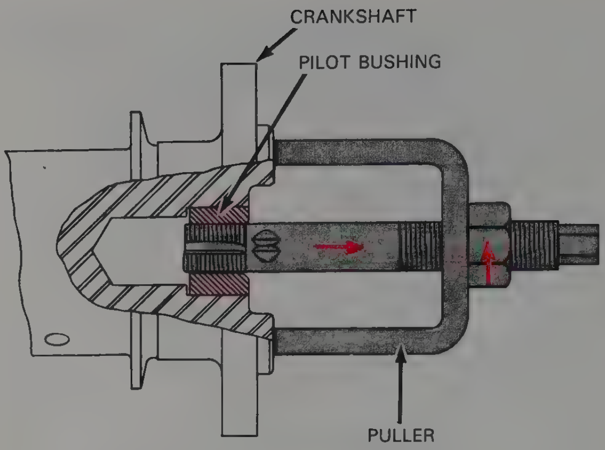


Fig. 26-16. Using threaded tip puller to remove clutch pilot bushing. Where ball bearings are used, an expandable finger tip puller should be used. (Oldsmobile)

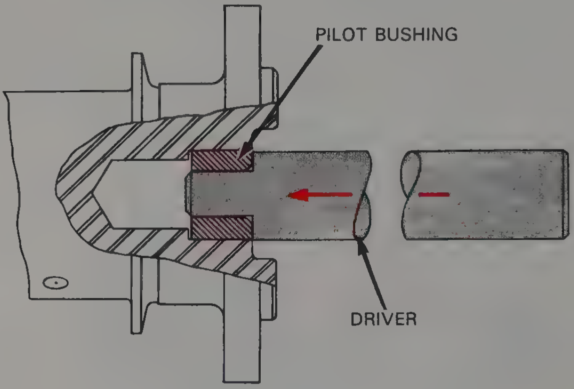


Fig. 26-17. Installing clutch pilot bushing with driver tool.

CLUTCH HOUSING MUST BE ALIGNED

The portion of the clutch housing to which the transmission is attached, must be properly aligned with the crankshaft centerline.

In instances where short throw-out bearing life, clutch chatter, transmission jumping out of gear, and early transmission input shaft bearing failure indicate possible housing misalignment, both housing bore and face runout should be checked. If the clutch housing has been removed, it is good practice to check the alignment following installation.

CHECKING CLUTCH HOUSING FACE AND BORE RUNOUT

Set up a dial indicator, as shown in Fig. 26-18. Check for clutch housing bore runout. Make certain the in-

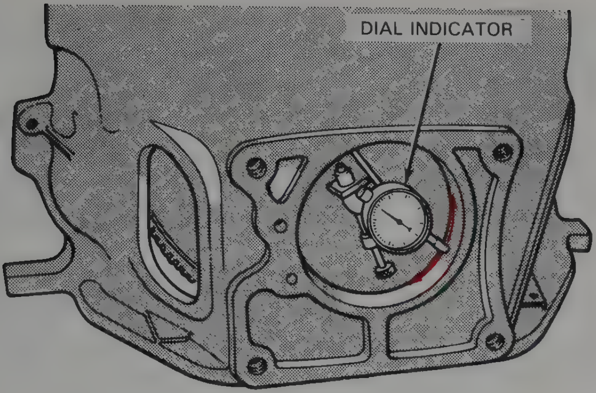


Fig. 26-18. Checking clutch housing bore runout. (Chrysler)

dicator stem rides against the machined bore surface. The indicator mounting bar must also be firmly affixed to the flywheel. The stem must be at right angles to the bore.

Zero the indicator and slowly turn the flywheel until the indicator stem has traveled completely around in the bore. Watch the indicator needle throughout the stem travel. The total needle travel (amount needle moved from both sides of the zero mark) represents double the actual runout. For example, if the total needle travel is .018 in. (0.46 mm), actual runout would be .009 in. (0.23 mm). See Fig. 26-18.

To check housing face runout, adjust the dial indicator so that the stem end rides against the machined face of the housing. The stem should be at right angles to the face. Turn the housing one complete turn while noting the total needle travel, Fig. 26-19.

If either bore or face runout exceeds specifications, the situation must be corrected by using thin shims between the housing and the engine block. Some manufacturers provide offset dowel pins that may be used to correct bore runout. When the offset dowels are used, shims must be employed to correct face runout. The use of offset dowel pins is shown in Fig. 26-20.

Whenever a correction for bore runout has been made, face runout should be rechecked. When face runout has been changed, bore runout must be rechecked.

Make careful adjustments and keep checking runout until it is brought within limits. In the event that bore or face runout cannot be brought within limits, or if an excessive shim thickness is required, the clutch housing must be replaced.

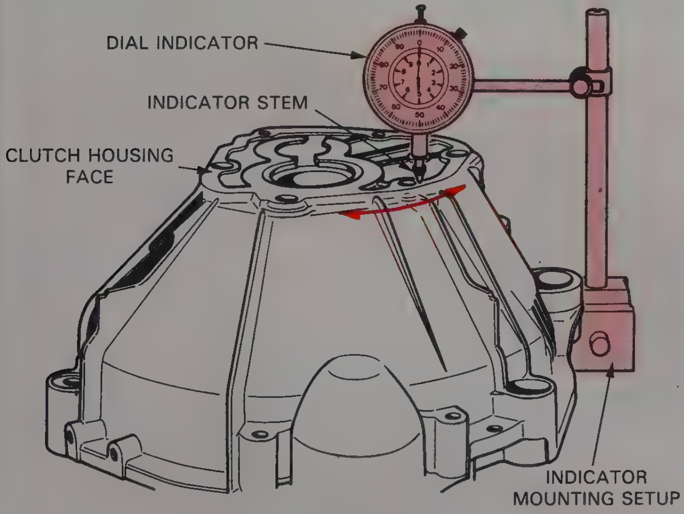


Fig. 26-19. Checking clutch housing face runout with a dial indicator. Housing is turned in a circle, keeping dial indicator stem in contact with mounting face (surface). (Peugeot)

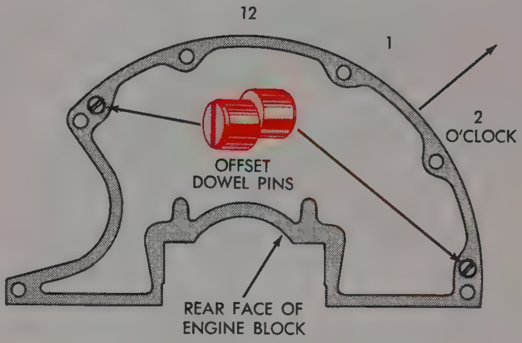


Fig. 26-20. Offset dowel pins may be used to correct bore runout. (Plymouth)

INSTALLING CLUTCH DISC AND PRESSURE PLATE ASSEMBLY

Installation of the clutch disc and pressure plate assembly is a relatively easy task. However, the job is often ruined or the service life seriously shortened by careless handling of the parts, improper tightening, and disc damage during transmission assembly.

Use care during assembly and follow the directions given in this chapter.

OIL CONTAMINATION

Oil leaking from the transmission, flywheel bolts, or rear main seal can quickly ruin the friction material on a new clutch disc.

Always check these two potential trouble spots carefully before installation of the clutch assembly. Repair as needed.

Remember: Oil leaks that flow into the clutch area must be stopped.

USE NEW CLUTCH DISC

It is advisable to install a new clutch disc when the clutch has been disassembled. When you consider the cost of a new disc compared to the overall costs, plus the assurance of proper operation and extended service life offered by the new disc, it is obviously poor practice to reinstall an old disc.

If for some reason the old disc must be considered for installation, check the disc friction facing for signs of looseness, glazing, wear, or oil soaking. Examine the hub torsional coil springs (cushion springs) to make certain they are not broken or loose. Look for any sign of warpage or cracking. Hub splines must be free of excessive wear. Generally, 0.03 in. (0.8 mm) is the maximum amount of hub spline wear allowable. If the disc is faulty in any way, it must be discarded. Refer to Fig. 26-21.

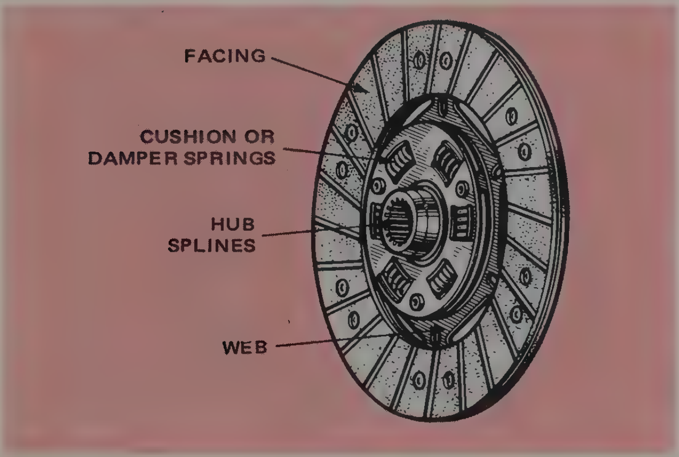


Fig. 26-21. If old clutch disc MUST be reinstalled, check these areas to determine serviceability. Remember — it is good practice to always install a NEW clutch disc. (Renault)

INSTALL CLUTCH DISC WITH CORRECT SIDE FACING FLYWHEEL

Examine the clutch disc friction facing. If one side is marked FLYWHEEL, place that side toward the flywheel. If neither side is marked, place the disc against the flywheel so that the hub and hub cushion or damper spring assembly will clear both the flywheel and pressure plate.

By careful study of the clutch and disc design, the correct side to place against the flywheel will become obvious. Note that the long side of the hub faces away from the flywheel in Fig. 26-25. It faces toward the flywheel in the setups pictured in Figs. 26-2 and 26-24.

USE CLUTCH DISC ALIGNING ARBOR

While holding the clutch disc and pressure plate assembly against the flywheel, pass a used transmission input shaft or an aligning arbor through the disc hub and into the pilot bearing. See Figs. 26-4 and 26-5.

The use of the clutch arbor or the input shaft will align the disc hub with the clutch pilot bearing. This will hold the parts in alignment while the clutch cover is attached.

Start all the clutch cover fasteners. Use lock washers. Tighten each fastener one turn. Continue around the fasteners, one turn per fastener, until the clutch cover is snug against the flywheel. At this time, use a torque wrench and tighten to specifications.

After the clutch cover is torqued, withdraw the clutch arbor. When the transmission is installed, the input shaft will pass through the disc hub and into the pilot bearing without difficulty.

INSTALL NEW THROW-OUT BEARING

A clutch, properly installed and properly used, will last for a long time. Even though the throw-out bearing appears to be good, it is good practice to install a NEW throw-out bearing whenever the clutch is overhauled. Failure to do this may result in bearing failure long before the clutch is worn out.

If, for some reason, the use of the old throw-out bearing MUST be considered, inspect it carefully. The bearing should spin freely but with enough drag to indicate the presence of grease. Press the bearing against a flat surface. While maintaining pressure, revolve the bearing. It should turn smoothly with no sign of catching or roughness.

In some cases, there are provisions for greasing, as on some truck throw-out bearings. If the bearing is mechanically sound, the addition of proper grease will render it fit for further service.

On some throw-out bearing assemblies, the bearing may be pressed from the sleeve. This allows the use of the old sleeve by merely pressing a new bearing into place. Other sleeve designs, such as the one pictured in Fig. 26-22, incorporate the bearing as an integral part of the sleeve.

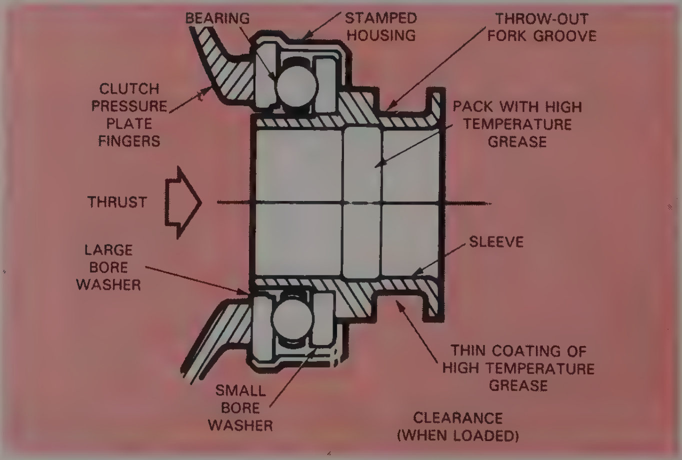


Fig. 26-22. In this throw-out bearing assembly, bearing is an integral part of sleeve. Note use of high temperature grease inside sleeve and on throw-out fork groove. (Federal-Mogul)

If a new throw-out bearing is forced onto the sleeve, use a press or a large vise. NEVER USE A HAMMER TO SEAT A THROW-OUT BEARING. Press the bearing on squarely and until fully seated.

Pack the inner groove of the throw-out sleeve with high temperature grease. Also coat the throw-out fork groove with a THIN coating of the same lubricant.

HYDRAULIC THROW-OUT BEARING ASSEMBLY

Some systems employ a hydraulic throw-out bearing assembly, which combines a throw-out bearing and a slave cylinder into a single unit. The slave cylinder encircles the transmission input shaft, and the bearing is permanently attached to the cylinder's piston, Fig. 26-23.

During operation, piston movement causes the throw-out bearing to travel in a linear direction, engaging or disengaging the pressure plate.

The hydraulic throw-out bearing and the slave cylinder must be serviced as an assembly. Do not try to disassemble the unit. The hydraulic lines will leak if they are disturbed.

LUBRICATE AND INSTALL CLUTCH THROW-OUT FORK

Lubricate the throw-out fork pivot with Lubriplate or similar grease. Wipe a THIN coating on the throw-out fork fingers.

Install the fork. Make cetain it is secured to the pivot, and that any internal retracting spring is in place. If the fork fingers are held to the throw-out bearing with retaining springs or clips, make certain the fingers are in their proper position and that the clips are in place. Install dust boot where used.

A typical throw-out fork and bearing setup is illustrated in Fig. 26-24.

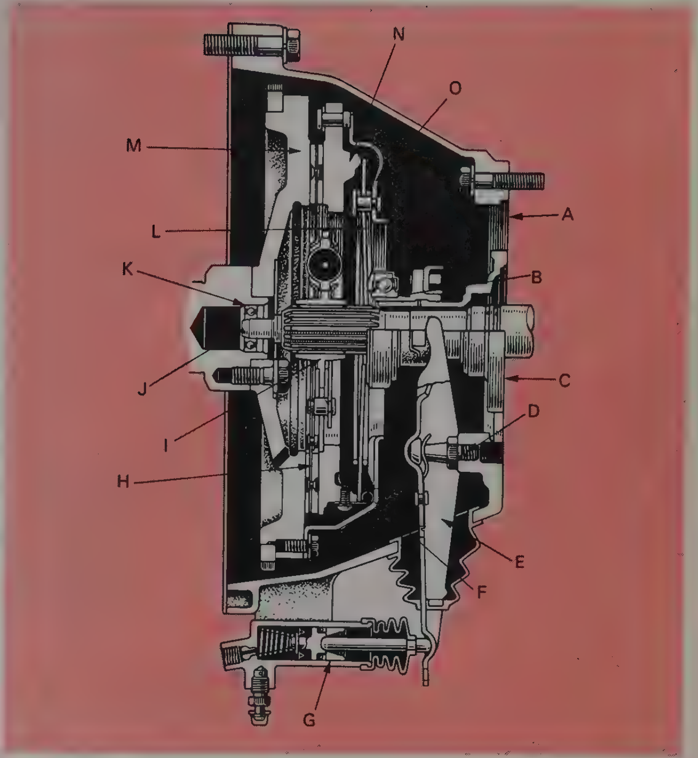


Fig. 26-24. Typical throw-out fork setup. A—Bell housing. B—Throw-out bearing. C—Transmission input shaft bearing retainer. D—Throw-out pivot ball stud. E—Throw-out fork. F—Spring. G—Hydraulic slave cylinder. H—Driven (clutch) disc. I—Clutch hub. J—Transmission input shaft. K—Pilot bearing. L—Diaphragm spring. M—Flywheel. N—Pressure plate. O—Clutch cover. (Toyota)

DO NOT DEPRESS CLUTCH PEDAL UNTIL TRANSMISSION IS FULLY IN PLACE

After the throw-out fork and throw-out bearing have been installed, and before the transmission is fully in place, avoid depressing the clutch pedal. To do so will

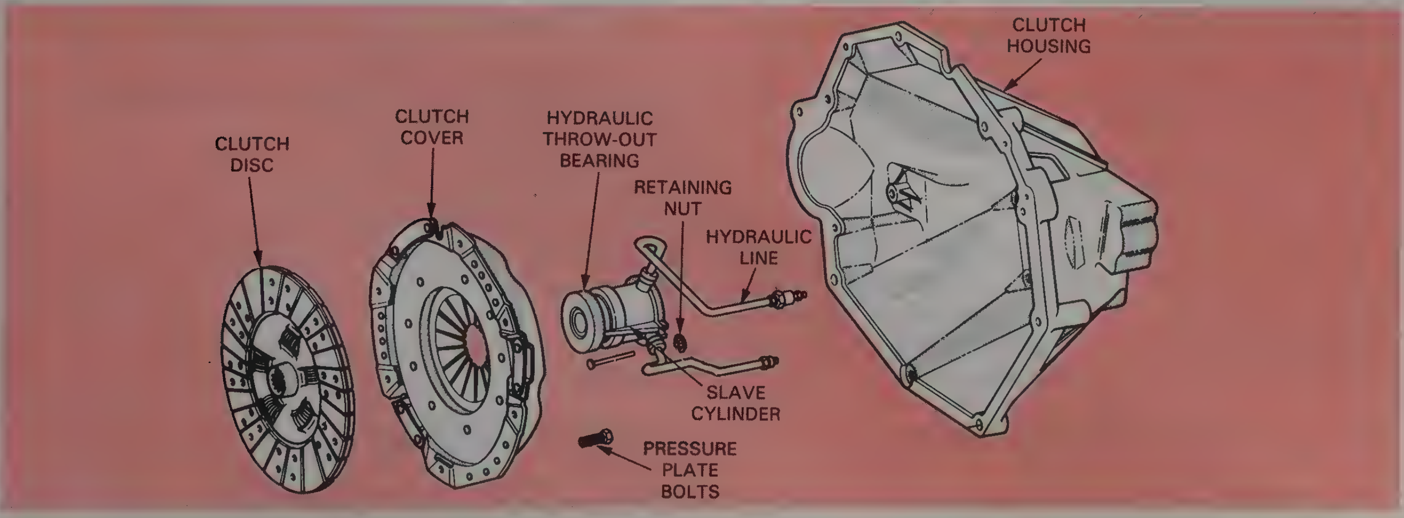


Fig. 26-23. Overall view of a hydraulic throw-out bearing assembly. (Jeep)

exert pressure on the clutch release fingers thus causing them to pull the pressure plate away from the disc. This would release the disc and allow it to drop down. This would prevent the transmission input shaft from passing through the disc hub and into the pilot bearing. Transmission installation would be impossible without disc realignment.

USE CARE WHEN INSTALLING TRANSMISSION

Tighten the transmission input shaft bearing retainer. See Fig. 26-24. Use a clean rag, dampened with solvent, to wipe the transmission input shaft until absolutely clean. Dry with a clean cloth. Apply a VERY THIN coat of high temperature grease to the portion of the input shaft bearing retainer that supports the throw-out bearing sleeve. DO NOT LUBRICATE THE INPUT SHAFT.

If the transmission shows any signs of oil leakage through the input shaft bearing, correct the leak before installation.

Place the transmission on a suitable stand and align with the engine crankshaft centerline. Place the transmission in gear. Pass the input shaft and transmission front bearing retainer through the throw-out bearing sleeve. When the input shaft splines strike the disc hub, turn the transmission output shaft to turn the input shaft. This will align the splines on the shaft and the hub. Push inward on the transmission as the output shaft is turned. When the splines are aligned, force the shaft through the hub and into the pilot bearing.

If the shaft resists entering the pilot, carefully move the rear of the transmission up and down and sideways.

When the input shaft is fully seated, the transmission front face will be touching the clutch housing. Install fasteners and bring to proper torque.

Never use transmission fasteners to draw the transmission into place. Never allow the weight of the transmission to hang on the input shaft and clutch disc — keep the transmission supported until the fasteners are in place. Fig. 26-25 shows a cross section of a typical clutch assembly with the transmission installed. Fig. 26-26 illustrates an exploded view of a clutch setup used with one type of manual transaxle.

ATTACH CLUTCH LINKAGE

Connect the clutch linkage assembly. Install all springs, washers, cotter pins, etc. Lubricate where required. Operate the clutch pedal several times to check linkage operation. Adjust pedal free play. Replace dust boot (where used) if cracked or torn.

PEDAL FREE PLAY OR FREE TRAVEL

The throw-out bearing should touch the clutch release fingers ONLY when the clutch pedal is depressed. (There is one clutch assembly that utilizes an automatic self-adjuster that removes pedal free play and keeps the throw-out bearing in contact with the release fingers at all times.)

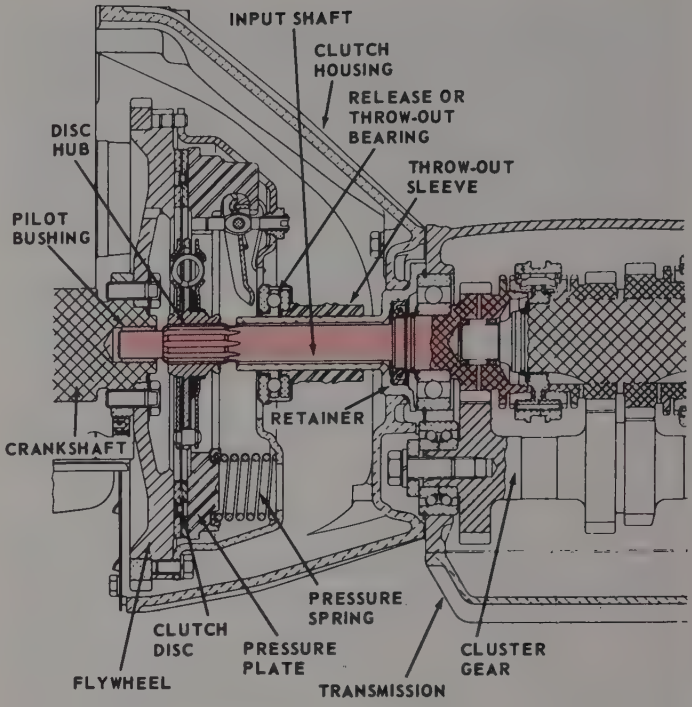


Fig. 26-25. Typical clutch assembly with transmission in place. Note how transmission input shaft passes through throw-out bearing, disc hub, and into pilot bushing.

Most clutch release assemblies must be adjusted, so that when the clutch pedal is released, the throw-out bearing moves away from the whirling clutch release fingers. This allows the throw-out bearing to stand still, thus prolonging its service life.

From the fully released position, the clutch pedal must be depressed a certain distance before the throw-out bearing is forced against the clutch release fingers. This distance or amount of pedal movement is called clutch pedal free play or free travel. See Fig. 26-27.

IMPORTANT CHECKS BEFORE ADJUSTING PEDAL FREE TRAVEL

Some clutch assemblies have provisions for only the free travel adjustment. Others however, provide adjustments for pedal height and total pedal travel. Where this is the case, both pedal height and total travel should be checked BEFORE ADJUSTING PEDAL FREE TRAVEL. Clutch return action should also be observed.

CLUTCH PEDAL HEIGHT

Where adjustment is possible, check the pedal height against specifications. Height measurement is usually

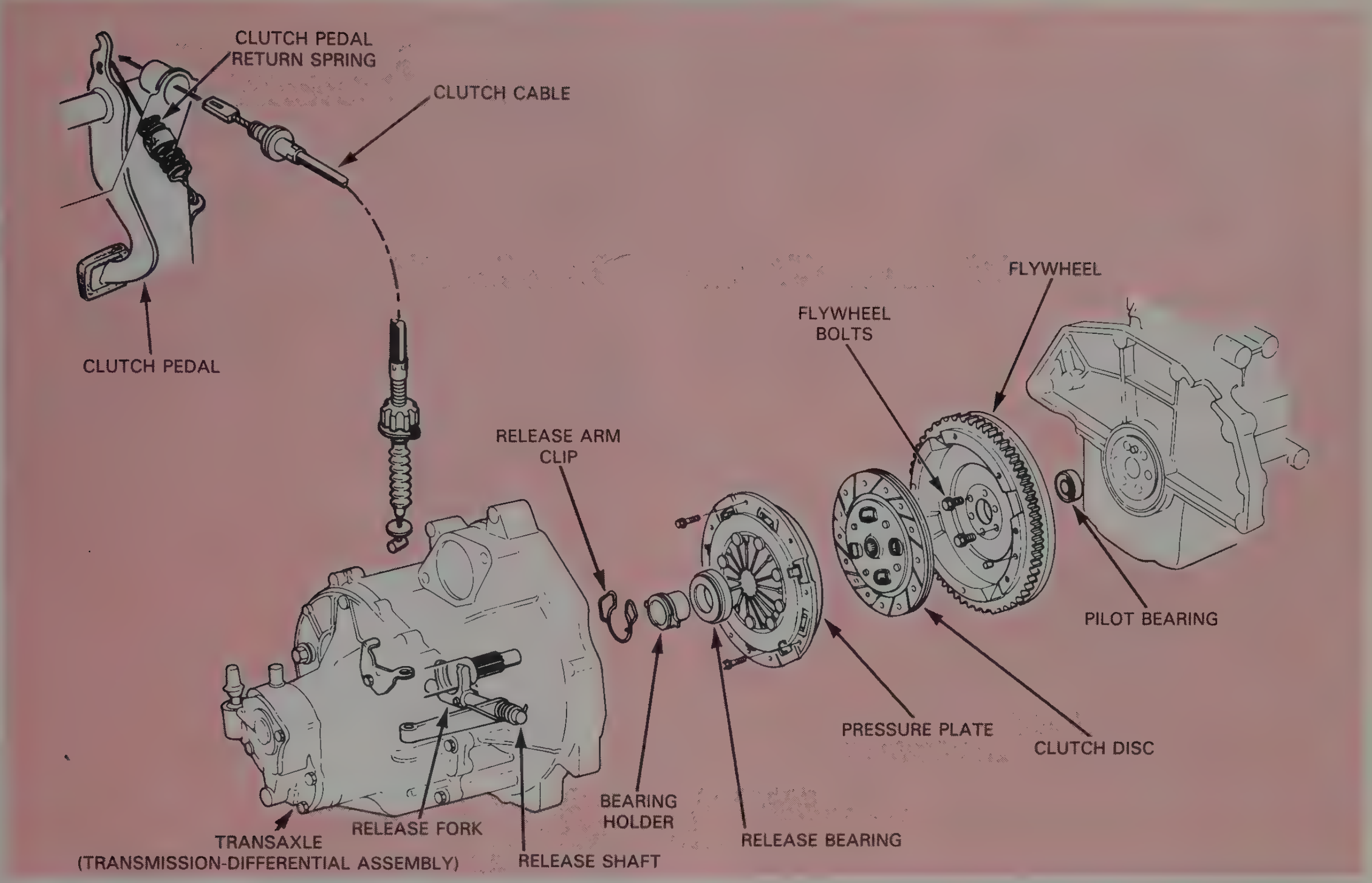

CLUTCH PEDAL RETURN SPRING
CLUTCH CABLE
CLUTCH PEDAL
FLYWHEEL
FLYWHEEL BOLTS
RELEASE ARM CLIP
PILOT BEARING
PRESSURE PLATE
CLUTCH DISC
BEARING HOLDER
RELEASE FORK
TRANSAXLE (TRANSMISSION-DIFFERENTIAL ASSEMBLY)
RELEASE SHAFT
RELEASE BEARING

Fig. 26-26. An exploded view of a cable operated clutch arrangement. This particular one is being used with a front-wheel drive transaxle. (Honda)

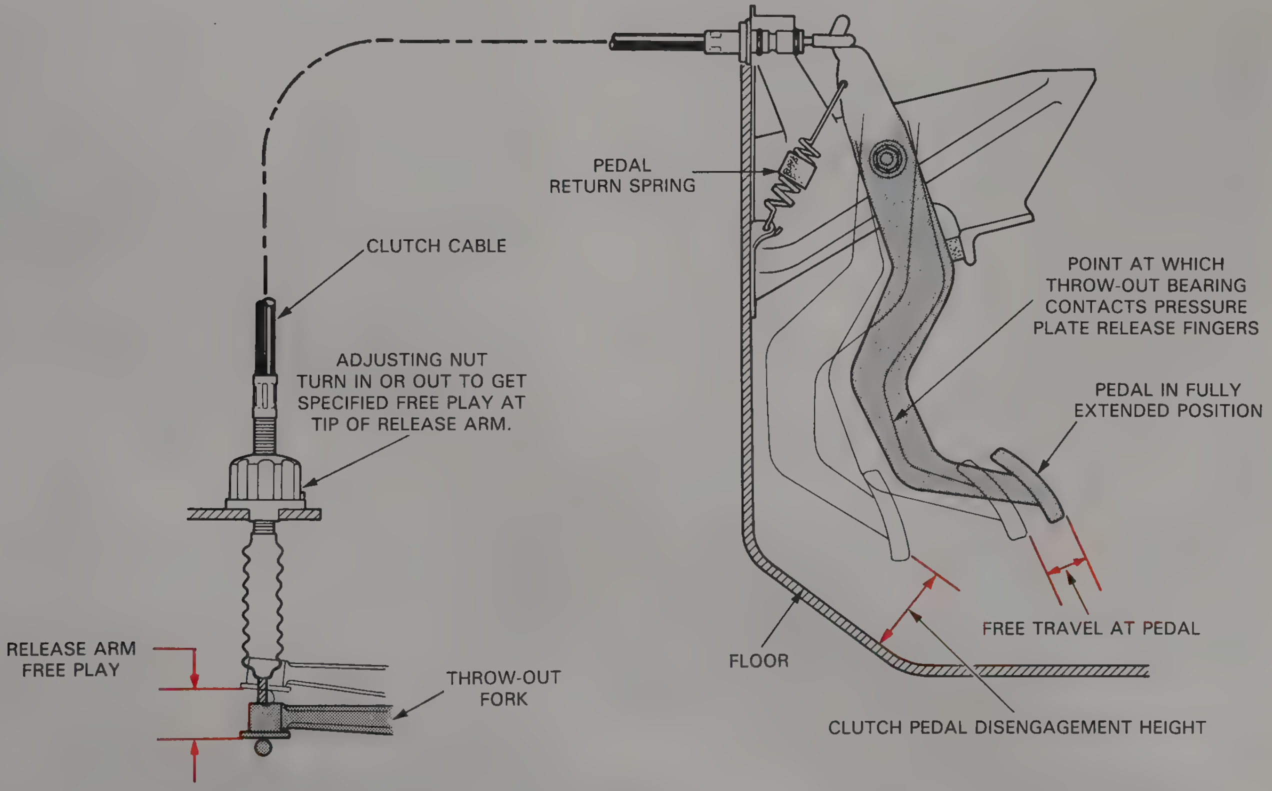

PEDAL RETURN SPRING
CLUTCH CABLE
ADJUSTING NUT TURN IN OR OUT TO GET SPECIFIED FREE PLAY AT TIP OF RELEASE ARM.
POINT AT WHICH THROW-OUT BEARING CONTACTS PRESSURE PLATE RELEASE FINGERS
PEDAL IN FULLY EXTENDED POSITION
RELEASE ARM FREE PLAY
THROW-OUT FORK
FLOOR
FREE TRAVEL AT PEDAL
CLUTCH PEDAL DISENGAGEMENT HEIGHT

Fig. 26-27. Clutch pedal free travel. Note clutch pedal disengagement height. (Honda)

determined by checking the distance from the pedal to a specific spot. It may also be checked by comparing clutch pedal height to that of the brake pedal.

Adjust pedal stop as required.

CLUTCH PEDAL TOTAL TRAVEL

Where required, check pedal total travel by measuring the distance the clutch pedal moves in traveling from the FULLY RELEASED TO THE FULLY EXTENDED position. Adjust as needed.

CLUTCH PEDAL RETURN ACTION

Check the clutch pedal return action. The pedal should return until firmly against the stop.

If the pedal sticks or catches, check for binding, interference, or a weak return spring.

In the event the pedal does not fully return, check the return spring or springs. Replace or adjust as required.

Never adjust the clutch linkage in an endeavor to force the clutch pedal to return the full distance. To do so will remove free travel and will ruin the throw-out bearing and possibly the entire clutch.

ADJUSTING CLUTCH PEDAL FREE TRAVEL

Make sure the clutch pedal is in the fully released position and that it is firmly against the pedal stop. Use a couple of fingers to depress the clutch pedal until the throw-out bearing engages the release fingers. The pedal should move (from fully released position) downward under moderate finger pressure. When the throw-out bearing engages the release fingers, a sharp increase in the resistance to downward movement will be felt.

The measured distance the pedal moves from the fully extended position to the point at which the release fingers are engaged, represents the amount of free travel. Average free travel is about 1 in. (25.4 mm). Check specifications.

If pedal free travel does not meet specifications, adjust the linkage as needed.

There are numerous linkage setups. Study the action as the clutch pedal is depressed. Find the adjustment device and move as required to provide proper free travel. Tighten the locknuts and replace snap rings and cotter pins after the adjustment is made. Check pedal free travel and readjust if necessary.

One linkage arrangement is pictured in Fig. 26-28. On this setup, pushing pedal (A) downward forces pushrod (B) to rotate cross shaft (C) thus forcing pushrod (D) to actuate throw-out fork (E). Note the adjustment threads on the end of pushrod (D) where it passes through swivel.

A somewhat similar linkage arrangement is pictured in Fig. 26-29. Note that the adjustment threads are on the upper pushrod end. To set pedal free travel on this setup, run both nuts (A) and (B) away from the swivel. Force the pushrod end toward the fire wall while pushing the cross shaft lever in the opposite direction.

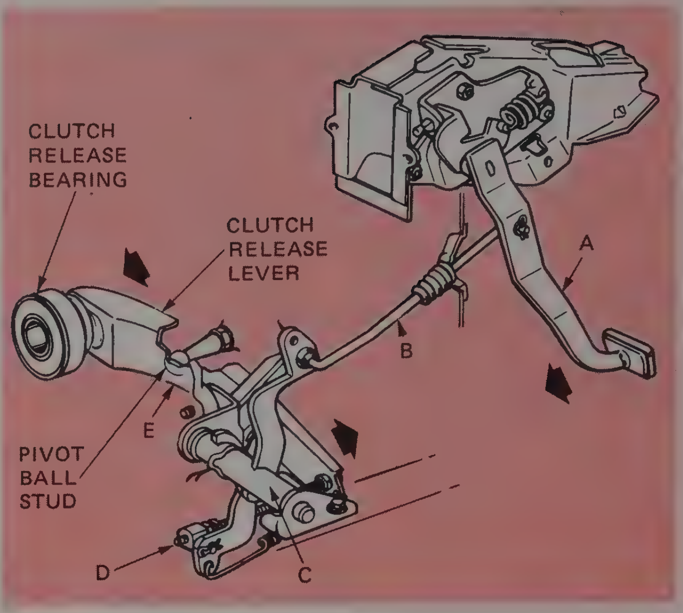


Fig. 26-28. One form of clutch linkage arrangement. (Federal-Mogul)

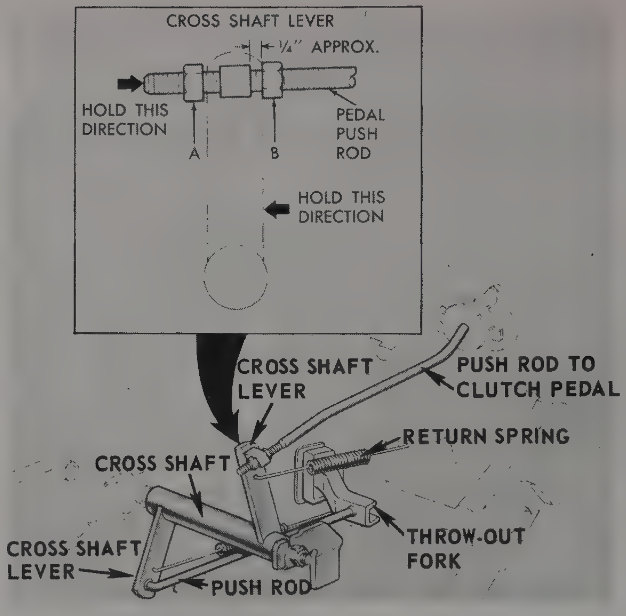


Fig. 26-29. Clutch pedal free travel adjustment setup.

Move the shaft lever until the throw-out bearing engages the release fingers. Hold in this position and run nut (B) up to within 1/4 in. (6.35 mm) of the shaft lever. Release lever and pushrod. Tighten nut (A) until the cross shaft lever is secured between both nuts. Check pedal for correct free travel, Fig. 26-29.

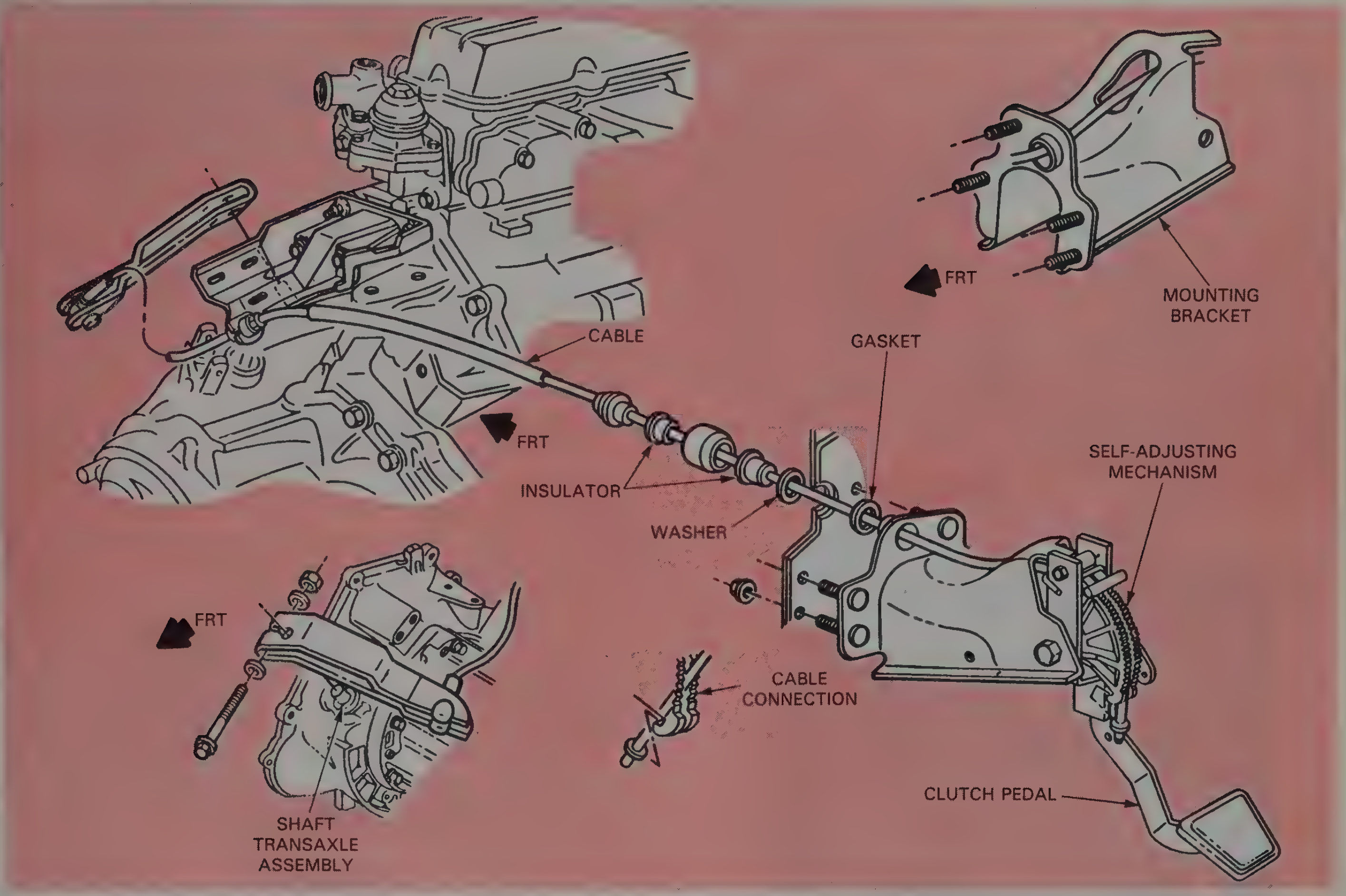

FRT
MOUNTING BRACKET
CABLE
GASKET
FRT
SELF-ADJUSTING MECHANISM
INSULATOR
WASHER
FRT
CABLE CONNECTION
CLUTCH PEDAL
SHAFT TRANSAXLE ASSEMBLY

Fig. 26-30. Overall view of one particular clutch mounting bracket and cable assembly. Use of a cable greatly simplifies linkage location and routing. Note self-adjusting mechanism used to take up part wear and cable stretch. (Chevrolet)

SELF-ADJUSTING CLUTCH LINKAGE

When self-adjusting linkage is used, check the clutch cable for kinks, cuts, and pinched areas. Be sure the self-adjusting clutch mechanism is clean and lightly lubricated, Fig. 26-30. Check for damaged parts on the self-adjusting mechanism such as worn pawl and detent (quadrant) teeth, or a loose mounting bracket.

Operate and check that the clutch releases fully. If equipped, be sure that the neutral start switch is properly secured and adjusted. Follow manufacturer's recommendations for the specific vehicle at hand. Figs. 26-30 and 26-31 show typical clutch release mechanisms. Study them closely.

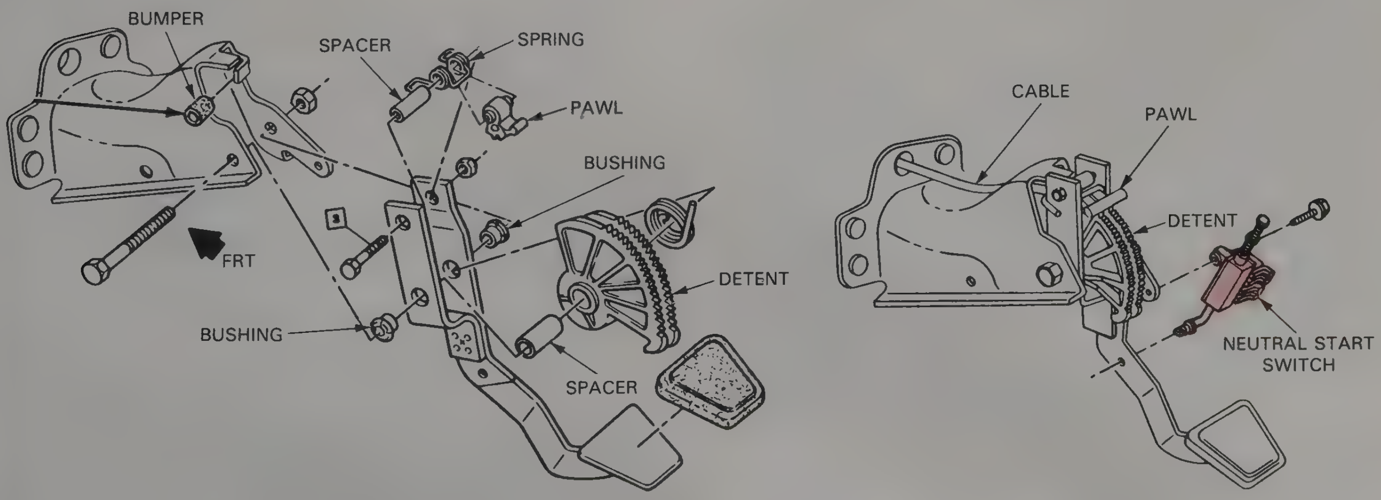

BUMPER
SPACER
SPRING
PAWL
BUSHING
FRT
DETENT
BUSHING
SPACER
CABLE
PAWL
DETENT
NEUTRAL START SWITCH

Fig. 26-31. Exploded view of a self-adjusting clutch pedal assembly. Note neutral start switch and its location. (Buick)

HYDRAULIC LINKAGE

Where a hydraulic slave cylinder is used to actuate the throw-out fork, check the master cylinder fluid level. Add fluid if required. Flush if old or contaminated. (See chapter on brakes for servicing hydraulic units.) Check master cylinder, slave cylinder, line, and connections for leaks if the fluid level is low.

Adjust pedal free travel to specifications. A typical slave cylinder setup is shown in Fig. 26-32. Note the adjustment nuts used to alter the length of the pushrod (4). An overall view of one type of hydraulic clutch linkage is pictured in Fig. 26-33. Never use mineral- or paraffin-based oils. They will damage rubber parts.

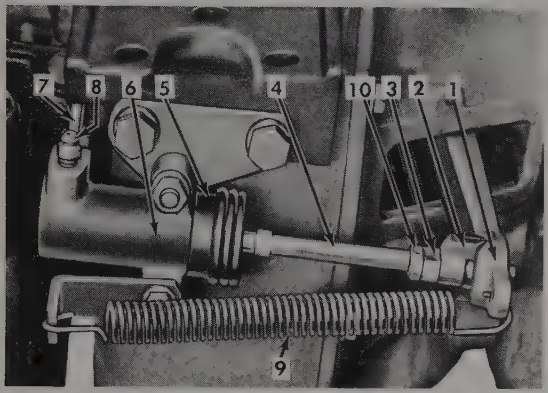


Fig. 26-32. Typical clutch hydraulic slave cylinder. Note how pedal free travel may be adjusted by loosening locknut (10) and turning adjustment nut (3) to change length of pushrod (4). Wedge (2) allows pushrod to actuate throw-out fork (1) without binding. 5—Boot. 6—Slave cylinder. 7—Hydraulic line from clutch master cylinder. 8—Bleeder valve. 9—Throw-out fork return spring. (G.M.C.)

REPLACE CLUTCH PILOT BEARING

When replacing a clutch, it is good practice to install a new pilot bearing or bushing. Installing a new clutch without replacing the bearing can cause damage to the transmission, clutch chatter, and other problems.

A hook type or expandable finger puller should be used to remove the bearing. Look at Fig. 26-34.

When installing the pilot bearing, clean out the bearing recess in the end of the crankshaft. Apply a thin coat of lithium base grease or equivalent to the bearing recess in the crankshaft. Install the bearing with the seal end facing the transmission. Place the pilot bearing on the driver and drive to the proper depth. Make sure the driver contacts only the outer bearing race. See Fig. 26-34. Lube bushing wick if used.

CLUTCH BREAK-IN

It is good practice to subject the newly installed clutch disc to around twenty starts. This will wear off the friction facing "fuzz" and seat the disc properly. Following this initial break-in, recheck the clutch pedal free travel.

STEAM CLEANING

When the engine and clutch housing are steam cleaned, a certain amount of moisture enters the housing. Rapid heating of the housing by the steam blast will also cause condensation.

If the clutch is not used for some time following steam cleaning, corrosion may form on the clutch unit. The clutch disc facing tends to absorb moisture, which can cause enough corrosion to literally "freeze" the flywheel, clutch disc, and pressure plate together. If this happens, the clutch assembly must be torn down in order to separate the units.

To prevent corrosion following steam cleaning, start the engine. Set the brakes. Shift into high gear. Run the engine at a moderate speed and slowly let the clutch pedal out until the engine tries to drive the car forward. Hold the pedal at this point and allow the clutch to "slip" for about five or six seconds. This will heat up the clutch enough to dry it.

SUMMARY

Coil springs or a diaphragm spring are commonly used to apply force to the pressure plate.

Always study the disassembled parts in an attempt to determine what caused the clutch trouble.

Be sure to disconnect the battery ground strap when working on the clutch.

The clutch cover and flywheel should be marked before removal to insure correct balance during reassembly.

Loosen each clutch cover fastener one turn at a time to prevent warping the cover during removal.

Do not clean the clutch disc or the throw-out bearing in solvent. Use a nonpetroleum cleaner on the pressure plate and flywheel.

Sand both the flywheel and pressure plate surfaces with fine emery cloth to break the mirror-like glaze.

For satisfactory service, flywheel and pressure plate surfaces must not be warped, scored, or badly checked.

If the pressure plate assembly is to be rebuilt, mark the pressure plate, release fingers, and cover to insure assembly in the same relative positions.

The pressure plate and flywheel friction surface, if not ruined, may be reground.

When reassembling the pressure plate, check the fit of the pressure plate drive lugs (where used) in the clutch cover. Adjust the release fingers.

Always install a new pilot bearing or bushing during a clutch overhaul. Lubricate pilot.

If problems so indicate, check the clutch housing

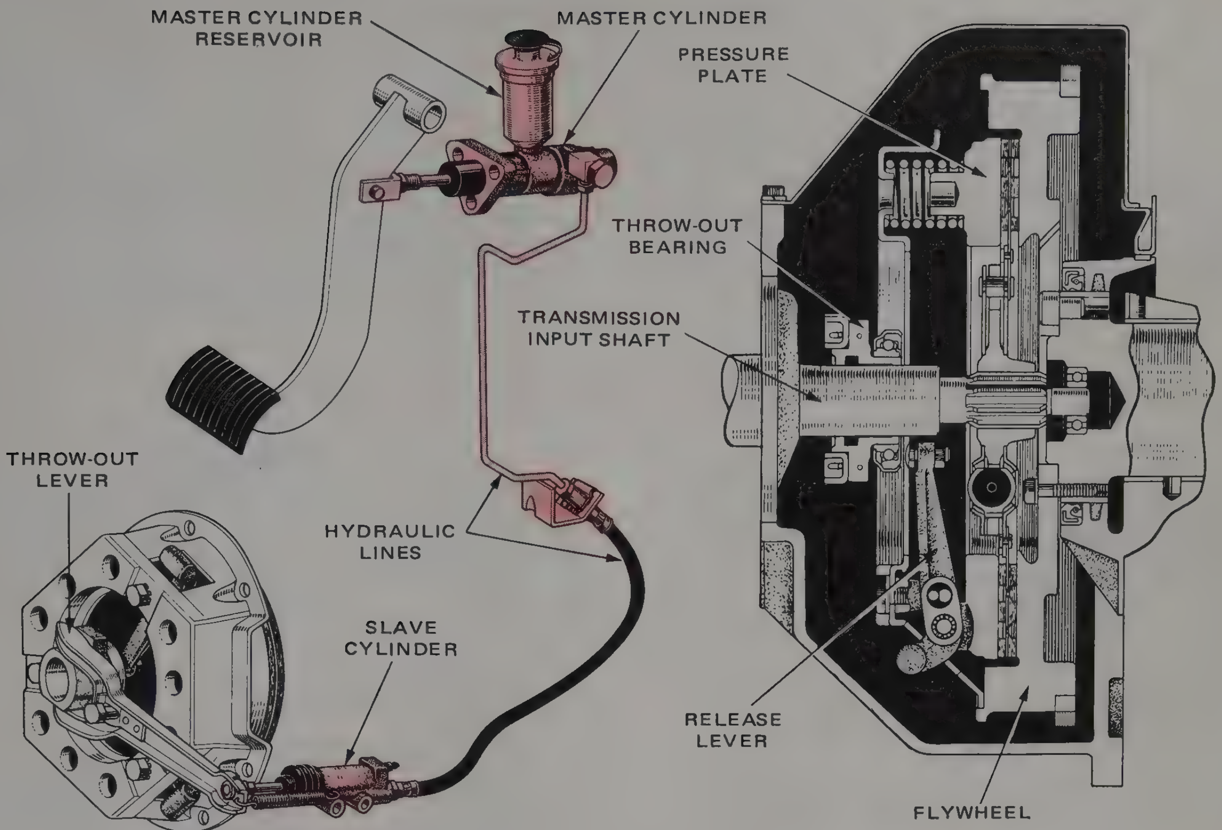

MASTER CYLINDER RESERVOIR
MASTER CYLINDER
PRESSURE PLATE
THROW-OUT BEARING
TRANSMISSION INPUT SHAFT
THROW-OUT LEVER
HYDRAULIC LINES
SLAVE CYLINDER
RELEASE LEVER
FLYWHEEL

Fig. 26-33. An overall view showing hydraulic clutch linkage and related assemblies. (Toyota)

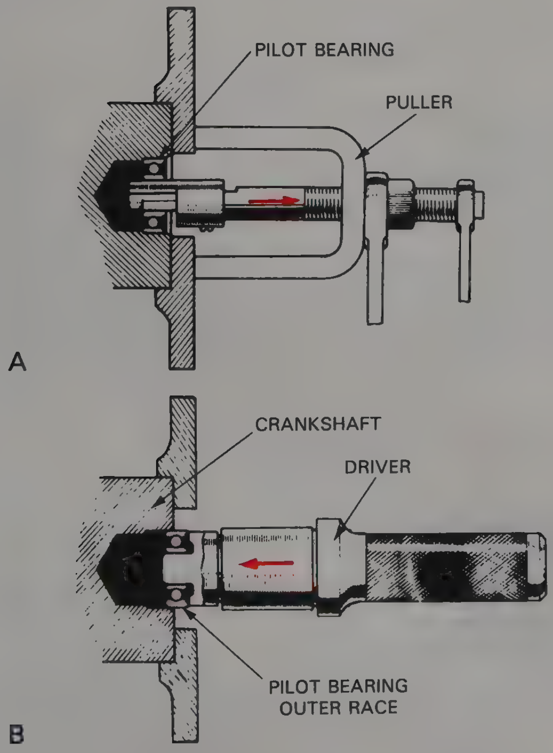

PILOT BEARING
PULLER
A
CRANKSHAFT
DRIVER
PILOT BEARING OUTER RACE
B

Fig. 26-34. Pilot bearing service. A—Using a hook type bearing puller to remove pilot bearing. B—Installing pilot bearing, using a proper fitting driver. Note how driver contacts bearing outer race only. (Toyota)

alignment — both bore and face runout. Shims and offset dowel pins are used to correct housing misalignment.

Be sure the flywheel and pressure plate surfaces are clean. To keep them clean, keep fingers off the new clutch disc friction lining and off the pressure plate and flywheel friction surfaces.

When installing the clutch, align the pressure plate. Align the clutch cover and flywheel marks. Tighten each cover fastener a little at a time until the cover touches the flywheel. Torque the fasteners.

Always use a new clutch disc during a clutch overhaul.

Install a new throw-out bearing.

Once the clutch, throw-out bearing, and fork have been installed, do not depress the clutch pedal until the transmission is in place.

Support the transmission while installing. Never let the weight of the transmission hang on the input shaft.

Attach clutch linkage, lubricate, and check alignment and action. Check clutch pedal height, total travel, and free travel.

Check hydraulic linkage master cylinder and slave cylinder for leaks. Flush if fluid is dirty.

Give the clutch a quick break-in and recheck pedal free travel. Readjust if needed.

Slip clutch for a few seconds following steam cleaning to prevent corrosion.

CLUTCH PROBLEM DIAGNOSIS

PROBLEM: CLUTCH SLIPS

Possible Cause	Correction
1. Insufficient pedal free travel.	1. Adjust free travel.
2. Disc facing soaked with oil or grease.	2. Clean clutch and pressure plate, replace disc. Correct source of oil contamination.
3. Broken or weak pressure plate spring or springs.	3. Rebuild or replace pressure plate.
4. Clutch disc facing worn.	4. Replace disc.
5. Hydraulic or mechanical linkage sticking.	5. Clean, align, and where needed, lubricate.

PROBLEM: CLUTCH CHATTERS AND/OR GRABS

Possible Cause	Correction
1. Disc facing oil or grease soaked.	1. Replace disc. Correct source of leak.
2. Burned disc facing.	2. Replace disc.
3. Warped or worn disc.	3. Replace disc.
4. Pressure plate warped.	4. Grind or replace.
5. Pressure plate or flywheel surface scored.	5. Grind or replace.
6. Pressure plate fingers bind.	6. Free fingers.
7. Clutch housing to transmission surface (face and bore) out of alignment with crankshaft centerline.	7. Align or replace housing.
8. Sticking linkage.	8. Free linkage.
9. Pilot bearing worn.	9. Install new pilot bearing.
10. Pressure plate release fingers improperly adjusted.	10. Adjust fingers.
11. Engine mounts worn or loose.	11. Tighten or replace mounts.
12. Transmission loose.	12. Tighten fasteners.
13. Rear spring shackles or axle housing control arms loose.	13. Tighten shackles or replace control arm insulators and tighten.
14. Worn splines or transmission input shaft.	14. Replace shaft.
15. Faulty throw-out bearing.	15. Replace throw-out bearing.

PROBLEM: CLUTCH WILL NOT RELEASE PROPERLY

Possible Cause	Correction
1. Excessive pedal free travel.	1. Adjust pedal travel.
2. Warped clutch disc.	2. Replace disc.
3. Clutch facing torn loose and folded over.	3. Replace disc.
4. Warped pressure plate.	4. Grind or replace.
5. Clutch housing misaligned.	5. Align housing.
6. Clutch disc hub binding on transmission input shaft.	6. Free hub.
7. Pilot bearing worn.	7. Replace pilot.
8. Faulty throw-out bearing.	8. Replace bearing.
9. Throw-out fork off pivot.	9. Install fork properly.
10. Clutch disc "frozen" (corroded) to flywheel and pressure plate.	10. Replace disc and clean flywheel and pressure plate.
11. Excessive idle speed.	11. Adjust idle speed.

PROBLEM: CLUTCH IS NOISY WHEN PEDAL IS DEPRESSED — ENGINE RUNNING

Possible Cause	Correction
1. Dry or worn throw-out bearing.	1. Replace bearing.
2. Worn pilot bearing.	2. Replace pilot.
3. Excessive total pedal travel.	3. Adjust travel.
4. Throw-out fork off pivot.	4. Install fork correctly.
5. Clutch housing misaligned.	5. Align housing.
6. Crankshaft end play excessive.	6. Correct end play.

PROBLEM: CLUTCH IS NOISY WHEN PEDAL IS DEPRESSED — ENGINE NOT RUNNING

Possible Cause	Correction
1. Dry, sticking linkage.	1. Lubricate and align.
2. Dry or scored throw-out bearing sleeve.	2. Lubricate or replace.
3. Pressure plate drive lugs rubbing clutch cover.	3. Lubricate with high temperature grease.

PROBLEM: CLUTCH NOISY WHEN PEDAL IS FULLY RELEASED — ENGINE RUNNING

Possible Cause	Correction
1. Insufficient pedal free travel.	1. Adjust free travel.
2. Clutch disc worn.	2. Replace disc.
3. Clutch disc springs broken.	3. Replace disc.
4. Clutch housing misaligned.	4. Align housing.
5. Worn disc hub splines.	5. Replace disc.
6. Worn input shaft splines.	6. Replace input shaft.
7. Sprung input shaft.	7. Replace input shaft.
8. Input shaft transmission bearing worn.	8. Replace transmission bearing.

PROBLEM: EXCESSIVE PEDAL PRESSURE

Possible Cause	Correction
1. Linkage needs lubrication.	1. Lubricate.
2. Pressure plate release fingers binding.	2. Free and lubricate.
3. Linkage misaligned.	3. Align linkage.
4. Throw-out bearing sleeve binding on transmission bearing retainer.	4. Free and lubricate.
5. Sticking linkage master or slave cylinder.	5. Clean or replace as needed.

PROBLEM: RAPID CLUTCH DISC WEAR

Possible Cause	Correction
1. Insufficient pedal free travel.	1. Adjust free travel.
2. Scored flywheel or pressure plate.	2. Grind or replace.
3. Driver rides the clutch (rests left foot on clutch while driving).	3. Instruct driver.
4. Driver races engine and slips clutch excessively during starting.	4. Instruct driver.
5. Driver holds car on hill by slipping clutch.	5. Instruct driver.
6. Weak pressure plate springs.	6. Rebuild or replace pressure plate assembly.

KNOW THESE TERMS

Single plate, Dry disc, Coil spring, Diaphragm spring, Clutch cover, Flywheel, Clutch friction surface, Pressure plate, Clutch release fingers, Pilot bushing, Pilot bearing, Clutch housing, Offset dowel pin, Clutch disc, Clutch arbor, Throw-out bearing, Self-adjusting linkage, Hydraulic linkage, Pedal free travel, Clutch pedal height, Slave cylinder, Throw-out lever, Throw-out sleeve, Clutch disc damper spring, Clutch disc hub, Glazing, Oil soaked, Cushion spring.

QUIZ - Chapter 26

1. Force is applied to the pressure plate by either Coil springs or a Diaphragm spring.
2. Before starting a clutch job, remove the Battery Ground Strap from the to prevent engine cranking.
3. Before removing the clutch cover fasteners, always:
   a. Wipe them off.
   b. Block the flywheel.
   c. Prick punch the cover and flywheel. ✓
   d. Check for disc warpage.
4. Loosen each clutch fastener all the way before proceeding to the next one. True or False?
5. The clutch disc and the trow-out bearing should never be cleaned in solvent.
6. The Flywheel and pressure plate should be cleaned in [illegible] solvent.
7. Never sand the pressure plate or flywheel friction surfaces. True or False?
8. Pressure plate assemblies can be rebuilt satisfactorily in many cases. True or False?
9. Before disassembly, the pressure plate assembly should be punch marked. Punch mark the Pressure plate, the release Fingros and the cover.
10. It is good practice to install a new Pilot bearing, a new trow-out bearing and a new Clutch disc on every clutch overhaul.
11. Clutch housing Face and bore runout should be checked if problems indicate possible housing misalignment.
12. The clutch disc, pressure plate, and flywheel friction surfaces must be kept spotlessly clean during assembly. True or False?
13. Oil the clutch disc hub splines before assembly. True or False?
14. Grease the input shaft splines. True or False?
15. When installing the pressure plate assembly to the

flywheel, always:
a. Align the prick punch marks.
b. Install the top fastener first.
c. Use a C-clamp to secure the unit.
d. Tighten each fastener fully before starting on the next one.

16. Align the clutch disc hub with the pilot bearing by using a clutch aligning arbor or a used transmission input shaft.

17. To assist in forcing the input shaft into the pilot bearing, it is permissible to use the transmission to clutch housing fasteners. True or False?

18. Before adjusting clutch pedal free travel, the clutch pedal height, total pedal travel and pedal return action should be checked.

19. Pedal free travel is generally around one inch or 25.4 mm.

20. Generally, clutch pedal free travel (play) is adjusted by:
a. Placing shims under the clutch cover.
b. Adjusting the clutch linkage.
c. Bending the pedal stop.
d. Aligning the clutch housing.

21. When replacing a clutch, it is advisable to install a new pilot bearing or bushing. True or False?

22. Insufficient pedal free travel can cause:
a. Clutch slipping.
b. Excessive throw-out bearing wear.
c. Rapid clutch disc wear.
d. All of the above.

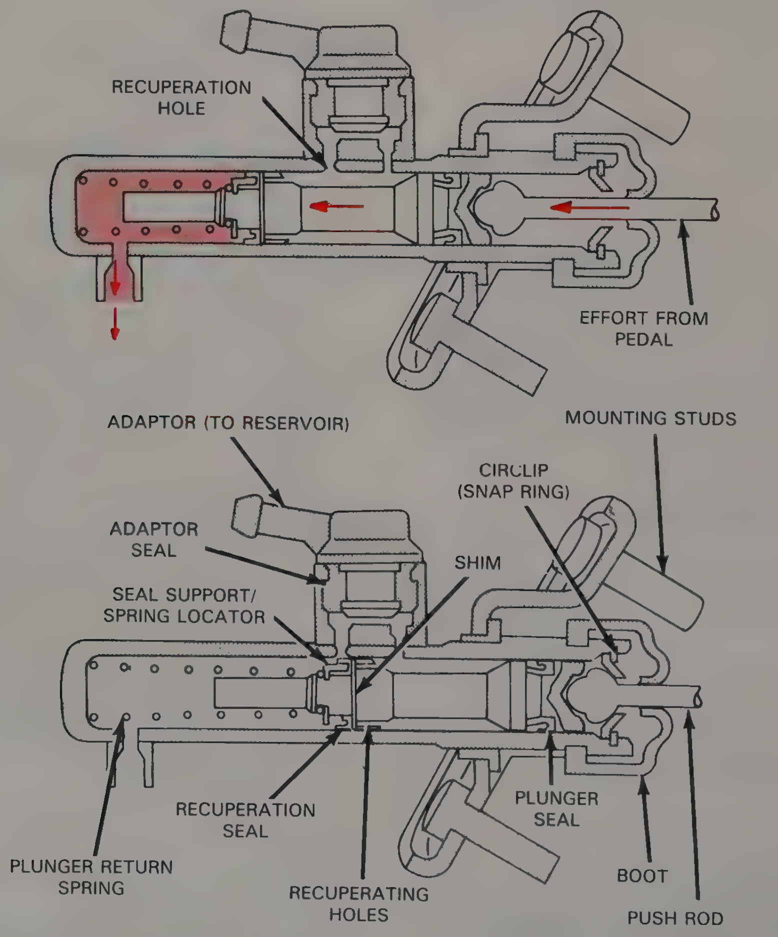
23. Excessive pedal free travel can cause:
a. Hard shifting.
b. Fast throw-out bearing wear.
c. Throw-out fork wear.
d. All of the above.

24. It is good practice to break in the clutch by starting and stopping the car a few times and then rechecking the pedal free travel. True or False?

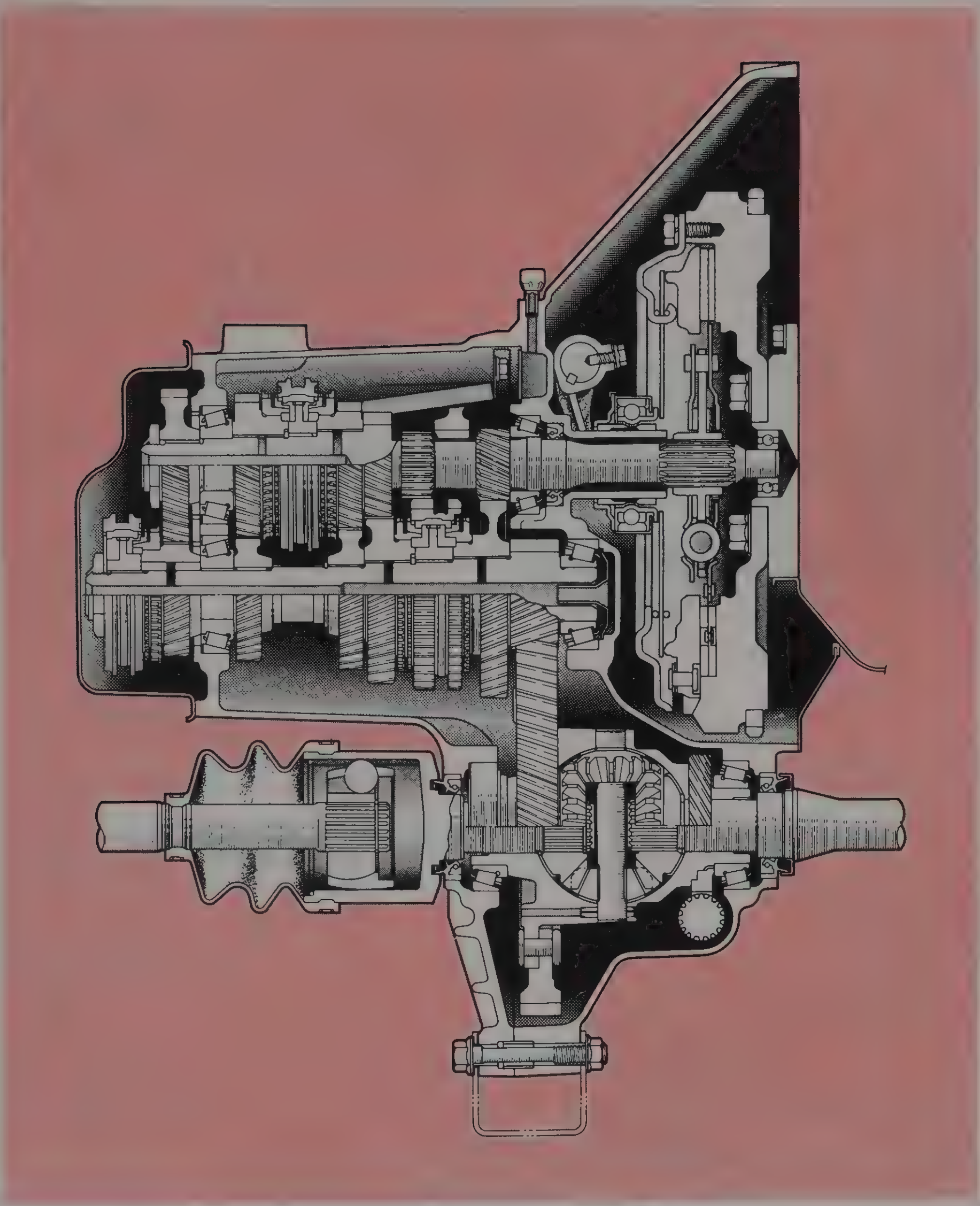
25. To prevent clutch corrosion following steam cleaning, the mechanic should:
a. Allow the car to stand for several hours before running.
b. Start the engine and slip the clutch.
c. Raise the rear end and spin the wheels.
d. Oil the clutch disc facing.

26. Most self-adjusting clutch setups use cable linkage. True or False?

27. Some vehicles use a hydraulic slave cylinder arrangement to operate the clutch throw-out fork.


RECUPERATION HOLE
EFFORT FROM PEDAL
ADAPTOR (TO RESERVOIR)
MOUNTING STUDS
CIRCLIP (SNAP RING)
ADAPTOR SEAL
SHIM
SEAL SUPPORT/ SPRING LOCATOR
RECUPERATION SEAL
PLUNGER SEAL
PLUNGER RETURN SPRING
BOOT
RECUPERATING HOLES
PUSH ROD

Hydraulic slave cross section. A—In operation. B—At rest. (Chevrolet)



This modern transaxle for a front-wheel drive car uses a clutch to engage and disengage engine and transaxle. (Mazda)

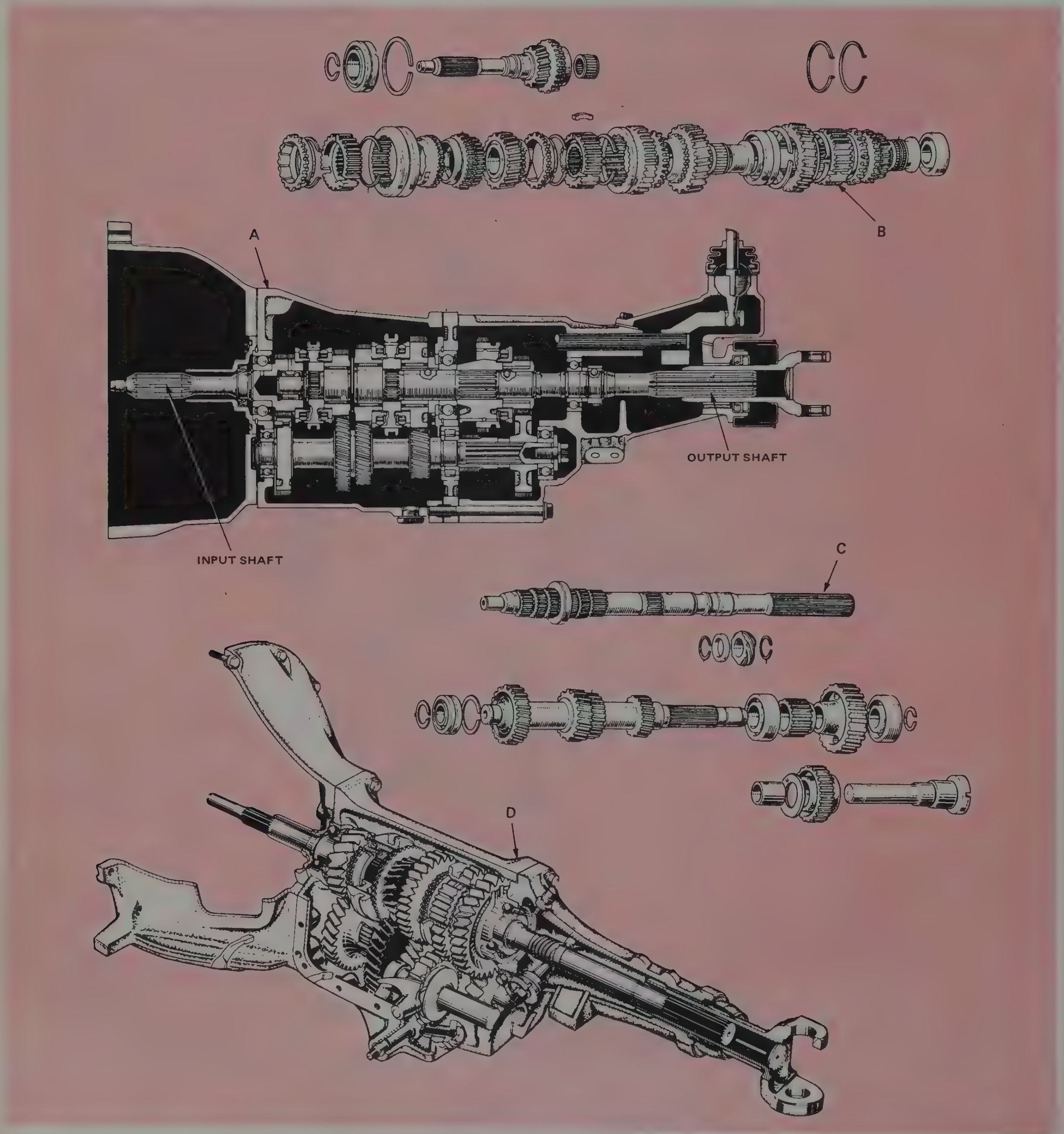
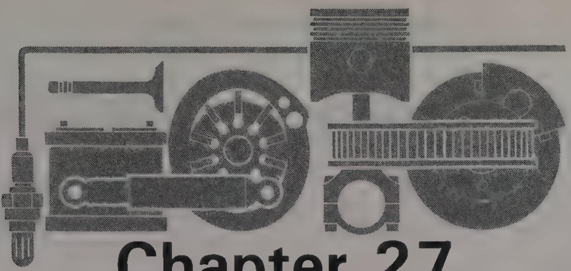


Fig. 27-1. Overdrive transmissions: A—Five speed transmission in which fifth gear is an overdrive gear. Input shaft turns about one-third slower than output shaft in fifth gear. B—Input shaft, gears, synchronizers, bearings, etc. C—Output shaft and cluster gear and idler assembly. D—Four speed transmission in which fourth gear is an overdrive gear. Can you identify the overdrive gear in each transmission? (Toyota and Dodge)



Chapter 27

MANUAL TRANSMISSION, OVERDRIVE, FOUR- AND FRONT-WHEEL DRIVE SERVICE

After studying this chapter, you will be able to:

- ☐ Explain manual transmission construction, operation, and service.
- ☐ Describe the construction, operation, and service of transaxles, overdrives, and transfer cases.
- ☐ Diagnose transmission and transaxle problems.
- ☐ Diagnose overdrive and transfer case troubles.

STANDARD (MANUAL) TRANSMISSION TYPES

Standard or manual transmissions for automobiles will be of either three, four, or five speed design.

The transmission may provide synchromesh shifting in some or in all forward speeds. An overdrive unit may be incorporated, Fig. 27-1. The transmission may mount to the clutch housing, or may be an integral part of the differential housing (transaxle design).

THREE SPEED TRANSMISSION

The three speed transmission provides drive ratios of around 2.79 to 1 in low or first gear (input shaft turns 2.79 times to rotate output shaft once), 1.70 to 1 in second gear, and 1 to 1 in high gear.

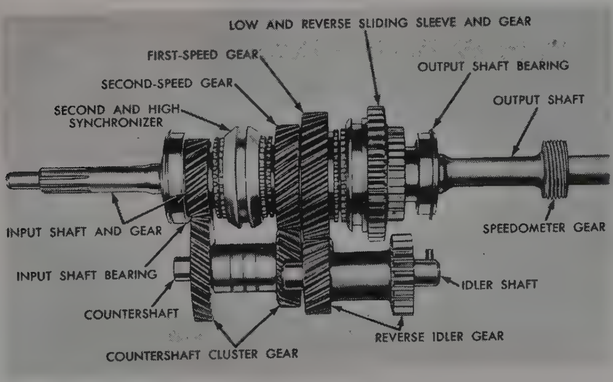

LOW AND REVERSE SLIDING SLEEVE AND GEAR
FIRST-SPEED GEAR
OUTPUT SHAFT BEARING
SECOND-SPEED GEAR
OUTPUT SHAFT
SECOND AND HIGH SYNCHRONIZER
INPUT SHAFT AND GEAR
SPEEDOMETER GEAR
INPUT SHAFT BEARING
IDLER SHAFT
COUNTERSHAFT
REVERSE IDLER GEAR
COUNTERSHAFT CLUSTER GEAR

Fig. 27-2. Working parts of a typical three speed, synchronized transmission. (Ford)

Remember that gear or drive ratios vary, depending on car weight, engine horsepower, and other factors.

Fig. 27-2 illustrates the working parts of a typical three speed transmission. You will note that this particular transmission uses constant mesh gears (gears that remain meshed together at all times). It is also fully synchronized in all forward speeds.

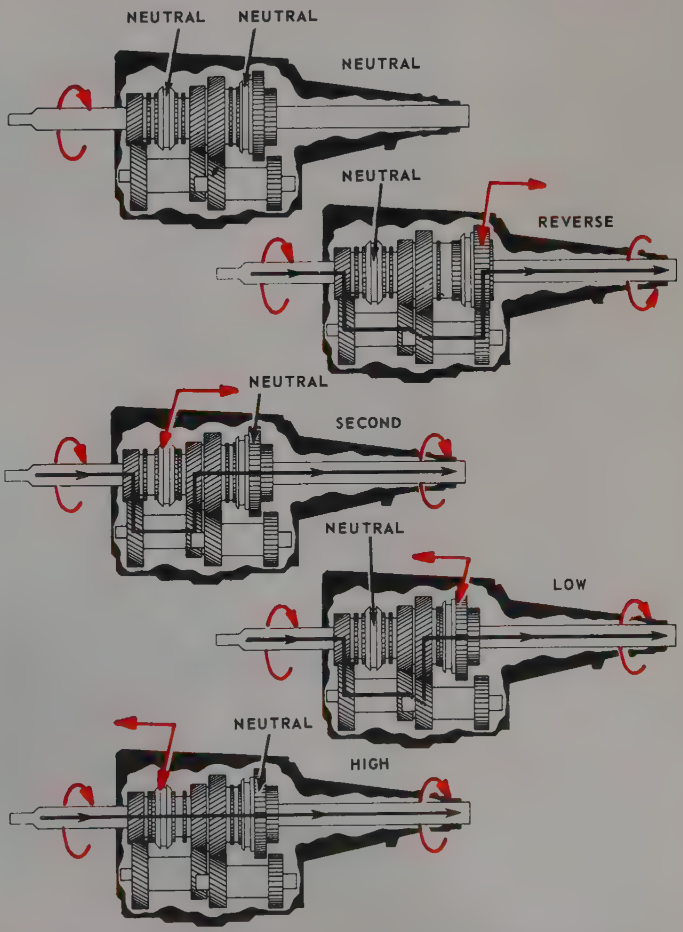

NEUTRAL
NEUTRAL
NEUTRAL
NEUTRAL
REVERSE
NEUTRAL
SECOND
NEUTRAL
LOW
NEUTRAL
HIGH

Fig. 27-3. Gear drive relationship in various speeds. Note shift movement indicated by arrows. (Pontiac)

Drive through the gears in neutral, first, second, high, and reverse, is pictured in Fig. 27-3. Study the positioning of the second and high synchronizer and the low and reverse sliding sleeve and gear.

FOUR SPEED TRANSMISSION

The four speed car transmission will generally have a first gear ratio similar to that of the three speed. By using the extra gear, the driver gets a wider latitude in selecting an appropriate gear for a given situation.

Typical ratios for four speeds are around 2.78 to 1 for first gear, 1.93 to 1 for second, 1.36 to 1 for third, and 1 to 1 for fourth or high gear. As with a three speed, these ratios vary.

Study the working parts in the four speed transmission shown in Fig. 27-4. Note that all forward gears are synchronized.

A different gear arrangement is used in the four speed transmission shown in Fig. 27-5.

FIVE SPEED TRANSMISSION—OVERDRIVE UNITS

The five speed transmission incorporating an overdrive gear is covered, along with other overdrive units, at the end of this chapter.

TRANSAXLE

The transmission in some applications is an integral part of the differential housing. Such construction is commonly referred to as a TRANSAXLE arrangement. See Fig. 27-6.

QUESTION OWNER

Talk to the owner about observations and complaints regarding transmission operation. Ask questions, if needed, to help pinpoint possible trouble areas.

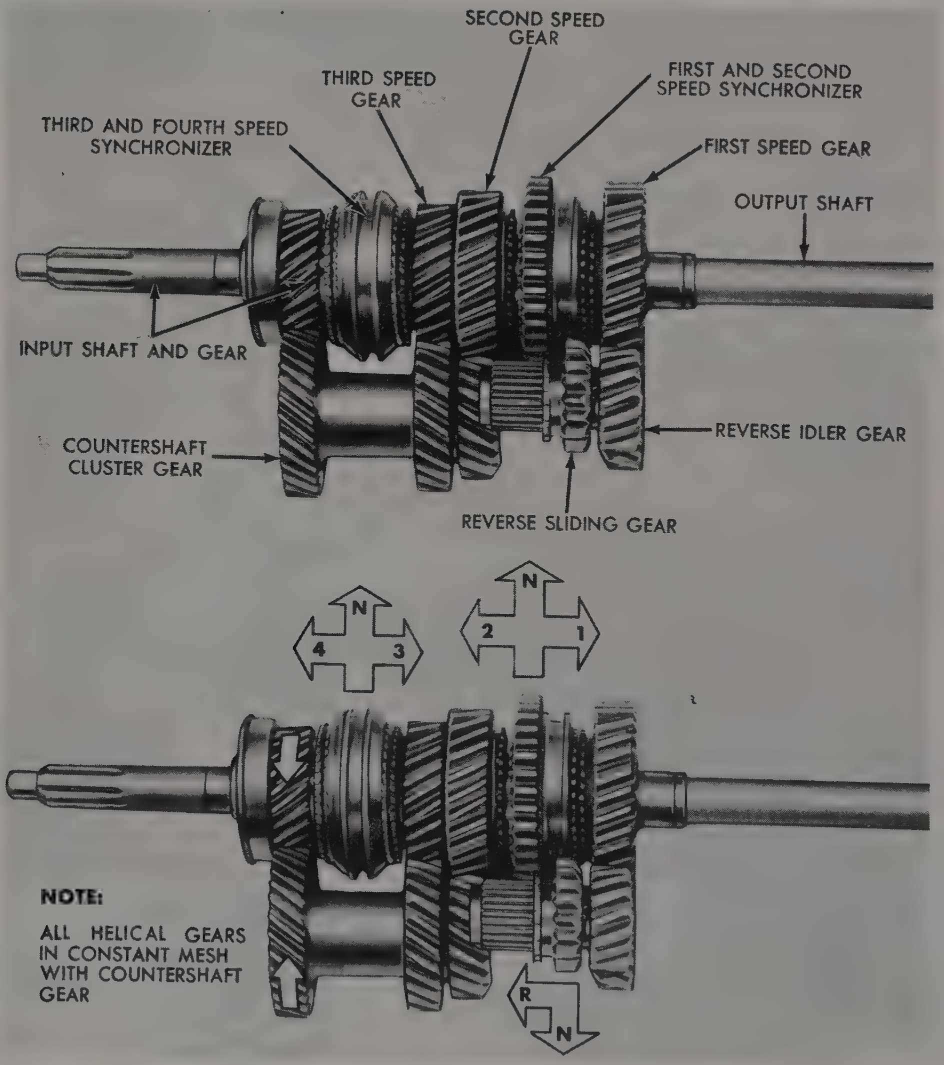

SECOND SPEED GEAR
THIRD SPEED GEAR
FIRST AND SECOND SPEED SYNCHRONIZER
THIRD AND FOURTH SPEED SYNCHRONIZER
FIRST SPEED GEAR
OUTPUT SHAFT
INPUT SHAFT AND GEAR
COUNTERSHAFT CLUSTER GEAR
REVERSE IDLER GEAR
REVERSE SLIDING GEAR
N
4
3
N
2
1
NOTE:
ALL HELICAL GEARS IN CONSTANT MESH WITH COUNTERSHAFT GEAR
R
N

Fig. 27-4. Working parts of a typical four speed, fully synchronized transmission. Arrows indicate shift movements. (Ford)

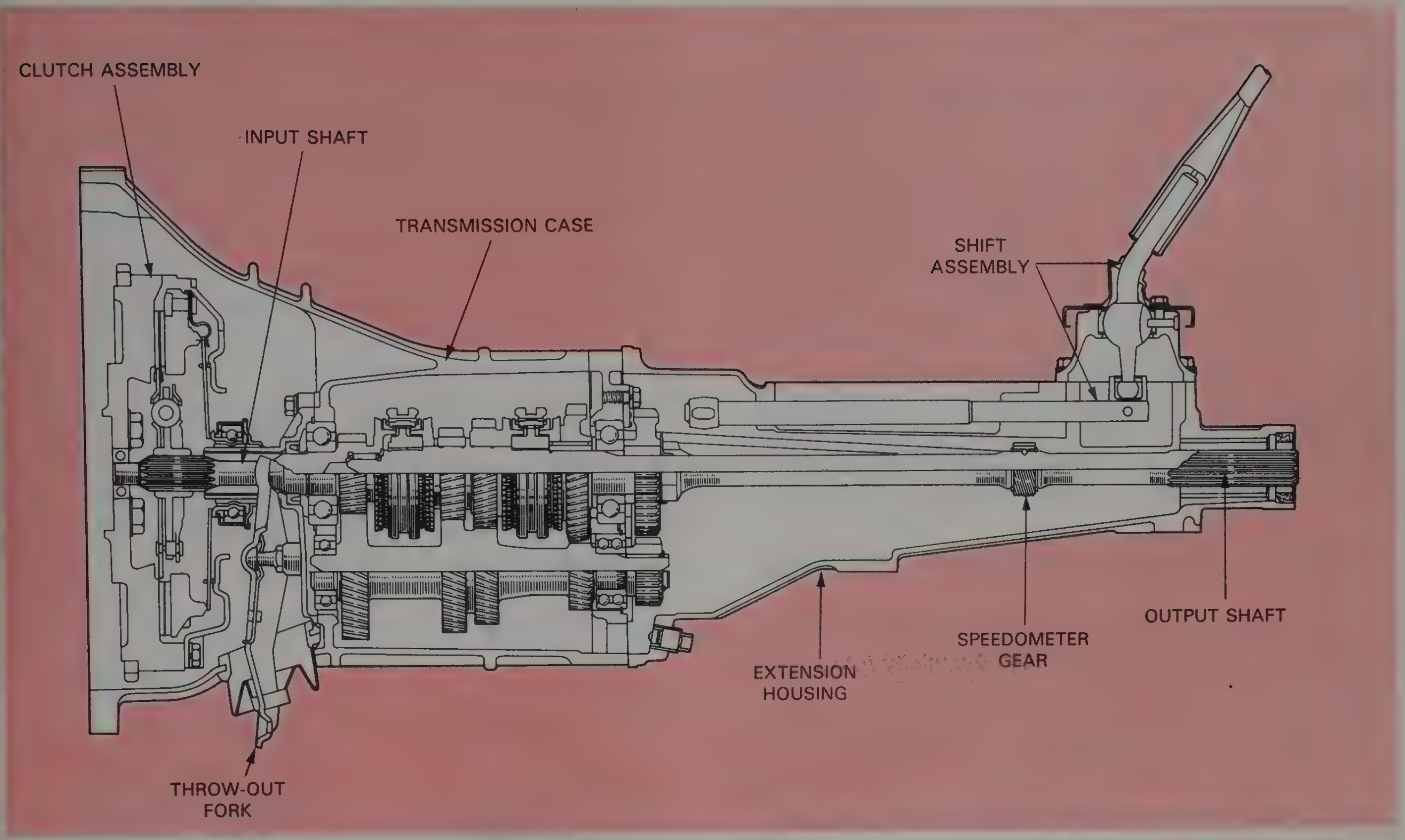

CLUTCH ASSEMBLY
INPUT SHAFT
TRANSMISSION CASE
SHIFT ASSEMBLY
OUTPUT SHAFT
SPEEDOMETER GEAR
EXTENSION HOUSING
THROW-OUT FORK

Fig. 27-5. Cross-sectional view of a four speed transmission. (Mazda)

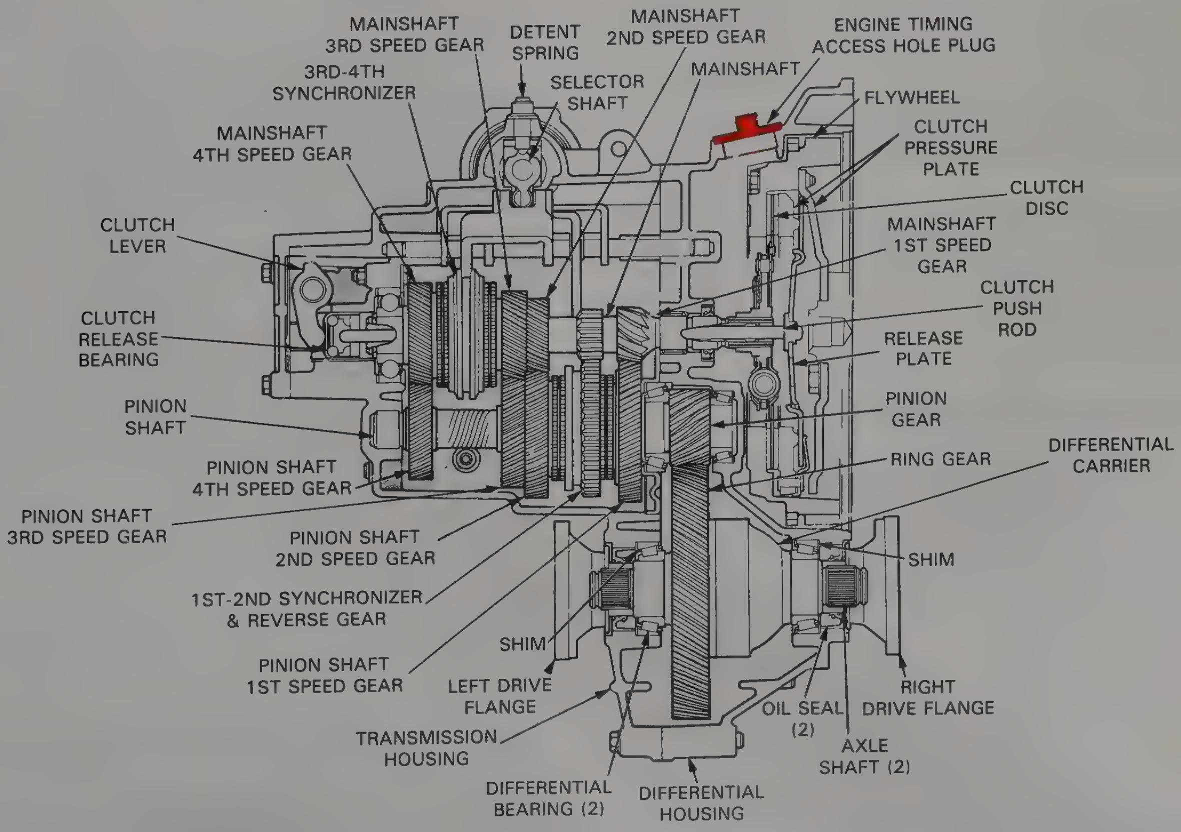

MAINSHAFT 3RD SPEED GEAR
DETENT SPRING
MAINSHAFT 2ND SPEED GEAR
ENGINE TIMING ACCESS HOLE PLUG
3RD-4TH SYNCHRONIZER
SELECTOR SHAFT
MAINSHAFT
FLYWHEEL
MAINSHAFT 4TH SPEED GEAR
CLUTCH PRESSURE PLATE
CLUTCH DISC
CLUTCH LEVER
MAINSHAFT 1ST SPEED GEAR
CLUTCH RELEASE BEARING
CLUTCH PUSH ROD
RELEASE PLATE
PINION SHAFT
PINION GEAR
PINION SHAFT 4TH SPEED GEAR
RING GEAR
DIFFERENTIAL CARRIER
PINION SHAFT 3RD SPEED GEAR
PINION SHAFT 2ND SPEED GEAR
SHIM
1ST-2ND SYNCHRONIZER & REVERSE GEAR
SHIM
PINION SHAFT 1ST SPEED GEAR
LEFT DRIVE FLANGE
RIGHT DRIVE FLANGE
OIL SEAL (2)
TRANSMISSION HOUSING
AXLE SHAFT (2)
DIFFERENTIAL BEARING (2)
DIFFERENTIAL HOUSING

Fig. 27-6. Cross-sectional view of a four speed manual transaxle. Note timing access hole plug. (Chrysler)

Make a list of possible problems based on the owner's statements. Then road test the transmission.

ROAD TEST TRANSMISSION WHEN POSSIBLE

Whenever possible, the transmission should be road tested. Some discretion must be used. Check the transmission lubricant level before road testing.

If a road test is performed, it should include some heavy acceleration and deceleration. Operate the car at various speeds. The route should include, when possible, some bumpy sections and a hill.

Check closely for abnormal noise, jumping out of gear, vibration, hard shifting, gear clash during shifting, and leaks. Note the gear (low, second, high) in which any problem was most evident.

CHECK CLUTCH AND SHIFT LINKAGE

If the owner complains of hard shifting, gear clash, or jumping out of gear, check the clutch and shift linkage operation before road testing.

The clutch pedal free travel must be within specifications. Excessive free travel will prevent full withdrawal of the pressure plate from the clutch disc. This will cause the transmission input shaft to continue turning, thus making shifting difficult and noisy.

The shift linkage must operate smoothly and should be adjusted so that the transmission is shifted FULLY INTO GEAR. Failure to provide full shift engagement can result in "jumping out of gear."

BEFORE PULLING TRANSMISSION, MAKE CERTAIN REMOVAL IS NECESSARY

Some transmission repairs may be performed with the transmission in the car. A few of these include shift linkage adjustment, shift cover overhaul, cover gasket replacement, rear oil seal replacement, and some overdrive internal work.

TRANSMISSION REMOVAL

If transmission removal is necessary, raise the car and drain the transmission.

Remove the shift linkage (mark to facilitate assembly). Remove the speedometer cable (use care as some connection units can be crushed with pliers). If equipped with an overdrive, disconnect the overdrive control cable and wiring. Where a drive line emergency brake is used, disconnect the linkage.

Disconnect the drive line or propeller shaft by "breaking" (partially dismantling) either the front or the rear universal joint. Prior to breaking the U-joint and lowering the shaft, mark the shaft and U-joint yoke or companion flange. This will let you reassemble the parts in their original positions. Failure to mark the parts can throw the joints out of phase and unbalance the entire propeller shaft assembly. See the chapter on DRIVE LINE SERVICE for complete details.

If the U-joint is of the cross and roller design, tape the loose roller bearings to the cross to prevent them from falling off. Fig. 27-7 shows a typical cross and roller U-joint being "broken" at the rear axle. Note the use of tape to hold the roller bearings in place.

Remove the transmission support-to-transmission fasteners. If the support cross member must be removed, support the engine with either a jack stand or engine support strap.

Some installations permit transmission removal with the support cross member in place. With this setup, the engine must usually be slightly raised at the rear. When raising the engine, be careful to avoid damage. If pushing upward on the pan, place a wide block of wood between pan and jack.

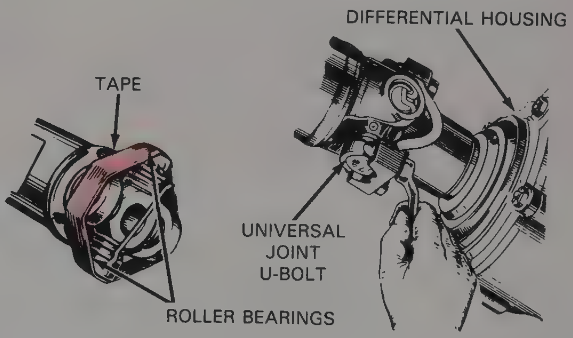


Fig. 27-7. Disconnecting drive line. Note use of tape to keep loose roller bearing cups in place. (Shell Oil)

USE A TRANSMISSION JACK STAND OR PILOT BOLTS

If the transmission is of a size that can be easily handled, remove either the two upper or two lower transmission-to-clutch housing fasteners. Install pilot bolts (dowel pins) in their place. Pilots should be long enough to provide support until input shaft is clear of the clutch disc hub. Remove the remaining fasteners. Slide the transmission away from the clutch housing. When free, lower to the floor.

If desired, a transmission jack stand can be used for removal. Attach the transmission firmly to the stand head. Tighten head adjustments. Remove transmission-to-clutch housing fasteners. Guide transmission away from housing.

CLEAN TRANSMISSION EXTERIOR

Clean the transmission exterior (outer surface) thoroughly. This will permit disassembly with a minimum amount of contamination.

FLUSH TRANSMISSION INTERIOR

Remove the transmission shift or inspection cover. Pour a pint or so of clean solvent into the case (oil was drained before transmission removal). Spin the input shaft. Continue turning the shaft while rocking the case to provide additional agitation. Drain and repeat process.

This flushing will remove enough of the heavy lubricant so that a visual inspection of the gear teeth may be made.

INSPECT GEARS, SHAFTS, SYNCHRONIZERS, AND OTHER PARTS

Turn the gears over slowly while carefully inspecting the teeth for chipping, galling, and excessive wear. Rock the gears on the shaft to determine approximate clearance.

Check end play of the cluster gear, reverse idler gear, and input and output shafts.

Inspect the synchronizer units for excessive looseness. Check the condition of the teeth engaged by the synchronizer clutch sleeve.

This initial inspection will help to indicate what the trouble is, how extensive, and what parts may be affected. Refer to Fig. 27-8.

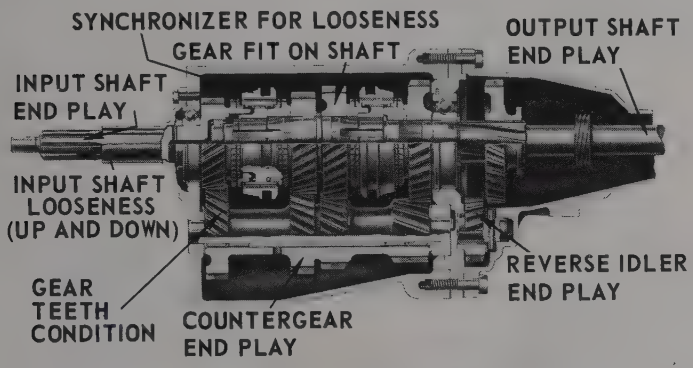


Fig. 27-8. Make these quick checks before dismantling transmission. (Chevrolet)

TRANSMISSION DISASSEMBLY PROCEDURE VARIES

Although basic transmission designs are similar, disassembly procedure and order of disassembly varies widely among the different makes and models.

Some transmissions require that the extension housing and output shaft be removed first. Others permit the removal of the input shaft first. Others require that the cluster shaft be lowered to the bottom of the case for removal of the output shaft and gears. Others do not.

Where one input shaft may require removal by passing into the case and out the cover hole, another may permit the shaft to be pulled directly from the case.

Some output shafts pull free with the extension housing. Others must be pulled separately. One setup may allow the output shaft to be withdrawn complete with gears. Another requires removal of the gears prior to shaft removal.

Due to space limitations, it is obvious that a text, such as this one, cannot cover the disassembly procedure for all transmissions.

Instead of dwelling on specific disassembly procedure and order, the transmission parts will be covered separately. One typical method of removal and installation will be shown. Inspection technique will be discussed.

USE MANUFACTURER'S SERVICE MANUAL

It is recommended that a service manual, covering the transmission at hand, be used. Disassembly and assembly order and technique will be shown. Exploded views will assist in the correct positioning of all parts. Specifications will be given.

GENERAL DISASSEMBLY PROCEDURES

Place the transmission in a suitable swivel type stand, such as shown in Fig. 27-9.

Follow the manufacturer's recommended order of part removal. If no manual is available, study the method of construction. This will provide clues as to which part should be removed first, second, etc. Careful study will also usually indicate how the parts must be removed.

The input shaft bearing retainer may be removed. Be sure to place alignment marks on transmission

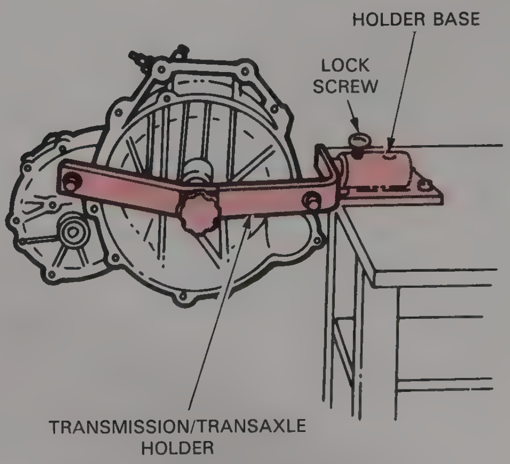


Fig. 27-9. Transmission-transaxle holding fixture makes repairs faster and easier. Holder base allows holder to be rotated and locked in a convenient work location. (Chevrolet)

housing and retainer before disassembly. See Fig. 27-10.

Remove the extension housing fasteners and pull the housing. This will usually allow either the output or the input shaft to be pulled far enough to determine exact removal procedure.

On some setups, lowering the cluster gear to the bottom of the case is required to permit shaft removal.

Proceed with the disassembly, being careful to avoid excessive hammering. Where a hammer is required, use a lead, plastic, brass, or rawhide hammer.

A drift punch, when used, should be of brass or soft steel.

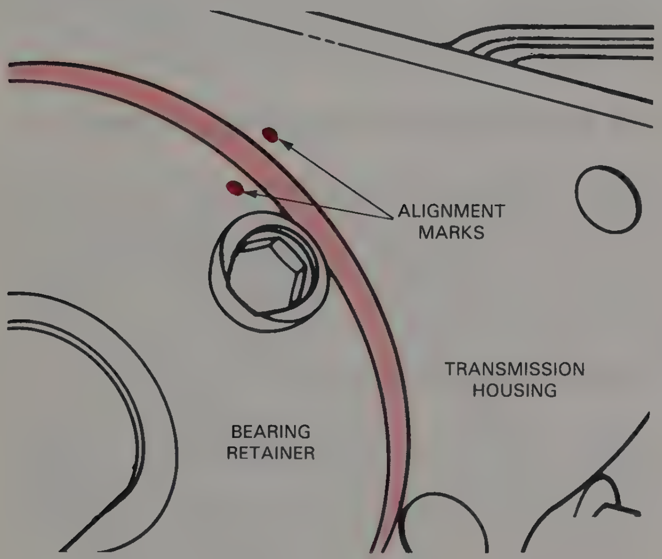


Fig. 27-10. Bearing retainer-to-transmission alignment marks. (Chevrolet)

Use care to avoid distorting snap rings in case they MUST be reused. Always use new snap rings during assembly when possible.

Remove the synchronizer unit as one part. Be certain to keep the cones or blocking rings with the unit and on the same side as originally installed.

Be careful not to lose any of the roller bearings from the gear end of the input shaft.

In some transmissions, the shift rails operate in the case rather than in a separate shift cover. See Fig. 27-11. This design generally necessitates shift fork and rail removal. Be careful to avoid losing any of the detent springs, detents, interlocks, or setscrews.

The cluster gear will usually contain a number of needle bearings. Do not lose any of them.

Remember: avoid the use of excessive pounding to loosen parts. Handle parts carefully to avoid chipping and nicking. Place all the small parts (loose needles and rollers, detent springs, detent plugs or balls) in a separate container to prevent loss.

Remove all the parts from the case.

Fig. 27-11 illustrates a typical four speed transmission. It is completely disassembled. Study the part names, positioning, and relationships.

CLEAN ALL PARTS THOROUGHLY

Clean all the gears, bearings, and shafts until absolutely CLEAN. Pay particular attention to the inside of the case and extension housing. Any tiny particles of chipped teeth or bearing that remain in a crevice or hard to reach spot will be loosened by the lubricant. They will eventually find their way into the moving parts – often with disastrous results. THE QUALITY OF AUTOMOTIVE REPAIR IS CLOSELY RELATED TO THOROUGHNESS OF CLEANING – BE METICULOUS IN ALL CLEANING.

INPUT SHAFT REMOVAL

The input shaft can often be removed by lowering the cluster gear and pulling the shaft and bearing from the front of the case. Other setups require passing the input shaft into the case (following removal of output shaft) and out the cover opening.

The input shaft in Fig. 27-12 is withdrawn by removing the front bearing retainer and two snap rings.

A special puller is then placed in the bearing snap ring groove. To prevent the input shaft from moving during the bearing removal, a yoke engages the input shaft clutch gear and the second speed gear clutch teeth on some units. The puller screws are tightened and the bearing will be pulled from the shaft. Look at Fig. 27-13.

The extension housing must be pulled and the output shaft assembly pulled back around 1/2 in. (12.7 mm). The front (pilot bearing end) of the input shaft is then lowered. By raising the drive gear end to clear the cluster gear, the shaft may be withdrawn. Refer to Fig. 27-14.

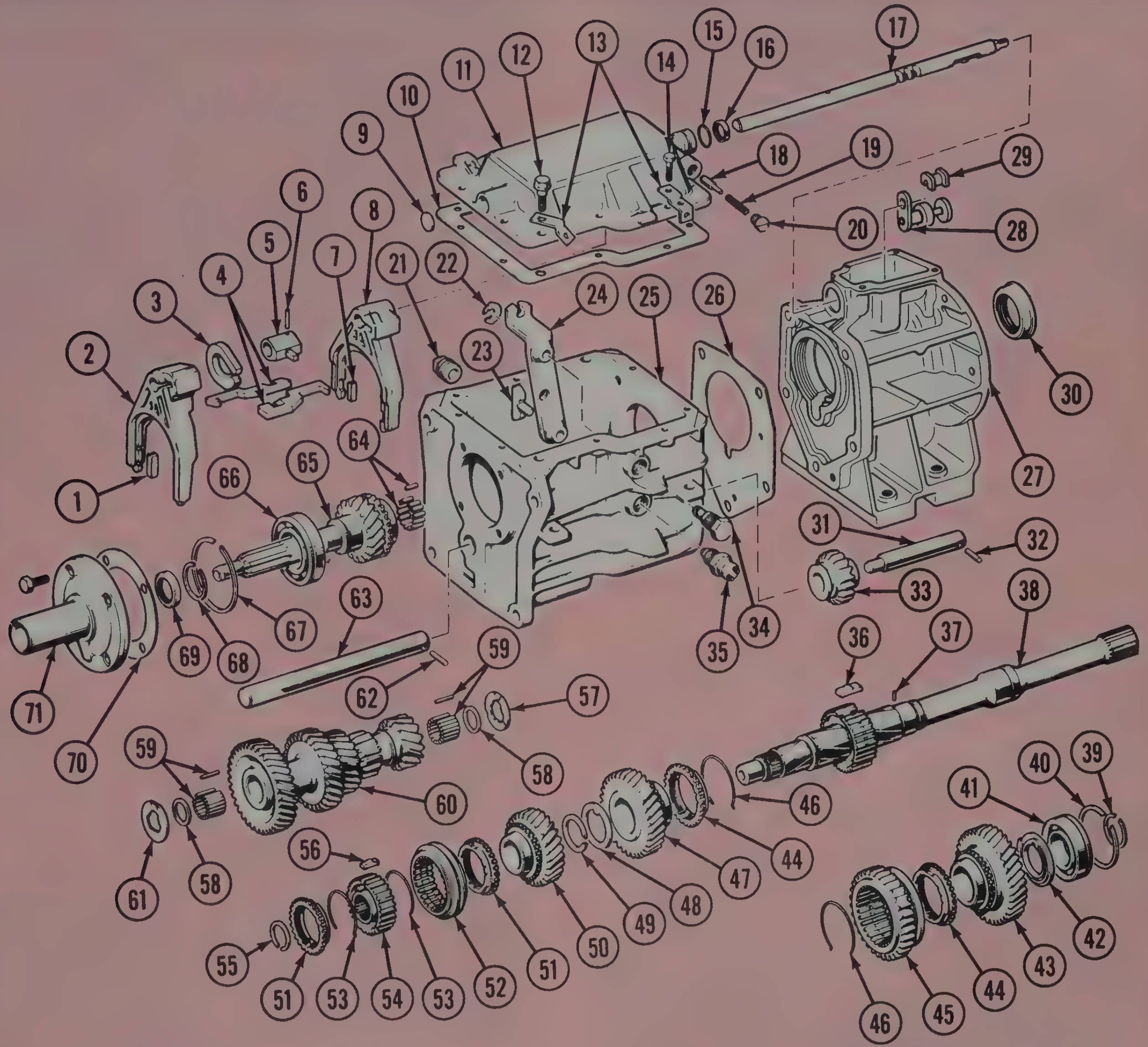
Remove the roller bearings from the gear end of the input shaft. Clean all parts.

INSPECTING INPUT SHAFT

Check the clutch pilot bearing end for wear and scoring. Examine the splines. They must be smooth and free of excessive wear.

Inspect the drive gear for wear, galling, pitting, and chipping. The drive gear clutch teeth must be free of wear. Check the clutch teeth closely for a tapered condition. The end of each clutch tooth is normally chamfered for easy engagement with the clutch sleeve. The remaining portion of the tooth body, however, must not be tapered. Taper or excessive wear can cause jumping out of gear.

Rotate each roller bearing while watching for signs



1. THIRD – FOURTH SHIFT INSERT
2. THIRD – FOURTH SHIFT FORK
3. SELECTOR INTERLOCK PLATE
4. SELECTOR ARM PLATE (2)
5. SELECTOR ARM
6. SELECTOR ARM ROLL PIN
7. FIRST – SECOND SHIFT FORK INSERT
8. FIRST – SECOND SHIFT FORK
9. SHIFT RAIL PLUG
10. TRANSMISSION COVER GASKET
11. TRANSMISSION COVER
12. TRANSMISSION COVER DOWEL BOLT (2)
13. CLIP
14. TRANSMISSION COVER BOLT (8)
15. SHIFT RAIL O-RING SEAL
16. SHIFT RAIL OIL SEAL
17. SHIFT RAIL
18. DETENT PLUNGER
19. DETENT SPRING
20. DETENT PLUG
21. FILL PLUG
22. REVERSE LEVER PIVOT BOLT C-CLIP
23. REVERSE LEVER FORK
24. REVERSE LEVER
25. TRANSMISSION CASE
26. GASKET
27. ADAPTER HOUSING
28. OFFSET LEVER
29. OFFSET LEVER INSERT
30. EXTENSION HOUSING OIL SEAL
31. REVERSE IDLER SHAFT
32. REVERSE IDLER SHAFT ROLL PIN
33. REVERSE IDLER GEAR
34. REVERSE LEVER PIVOT BOLT
35. BACKUP LAMP SWITCH
36. FIRST – SECOND SYNCHRONIZER INSERT (3)
37. FIRST GEAR ROLL PIN
38. OUTPUT SHAFT AND HUB ASSEMBLY
39. REAR BEARING RETAINING SNAP RING
40. REAR BEARING LOCATING SNAP RING
41. REAR BEARING
42. FIRST GEAR THRUST WASHER
43. FIRST GEAR
44. FIRST – SECOND SYNCHRONIZER BLOCKING RING (2)
45. FIRST – REVERSE SLEEVE AND GEAR
46. FIRST – SECOND SYNCHRONIZER INSERT SPRING (2)
47. SECOND GEAR
48. SECOND GEAR THRUST WASHER (TABBED)
49. SECOND GEAR SNAP RING
50. THIRD GEAR
51. THIRD – FOURTH SYNCHRONIZER BLOCKING RING (2)
52. THIRD – FOURTH SYNCHRONIZER SLEEVE
53. THIRD – FOURTH SYNCHRONIZER INSERT SPRING (2)
54. THIRD – FOURTH SYNCHRONIZER HUB
55. OUTPUT SHAFT SNAP RING
56. THIRD – FOURTH SYNCHRONIZER INSERT (3)
57. COUNTERSHAFT GEAR REAR THRUST WASHER (METAL)
58. COUNTERSHAFT NEEDLE BEARING RETAINER (2)
59. COUNTERSHAFT NEEDLE BEARING (50)
60. COUNTERSHAFT GEAR
61. COUNTERSHAFT GEAR FRONT THRUST WASHER (PLASTIC)
62. COUNTERSHAFT ROLL PIN
63. COUNTERSHAFT
64. CLUTCH SHAFT ROLLER BEARINGS (15)
65. CLUTCH SHAFT
66. FRONT BEARING
67. FRONT BEARING LOCATING SNAP RING
68. FRONT BEARING RETAINING SNAP RING
69. FRONT BEARING CAP OIL SEAL
70. FRONT BEARING CAP GASKET
71. FRONT BEARING CAP

Fig. 27-11. Exploded view of a four speed transmission. (Jeep)

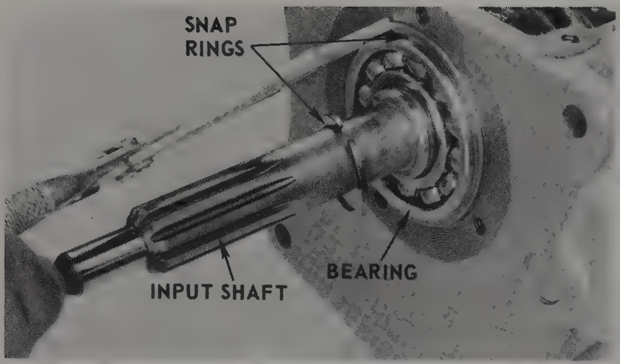

SNAP RINGS
BEARING
INPUT SHAFT

Fig. 27-12. Preparing to pull input shaft by first removing bearing snap rings. Retainer has already been removed. (American Motors)

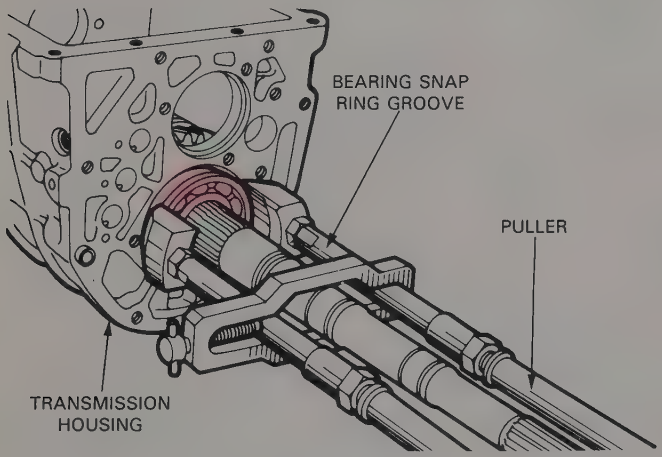

BEARING SNAP RING GROOVE
PULLER
TRANSMISSION HOUSING

Fig. 27-13. Pulling input shaft bearing. (Dodge)

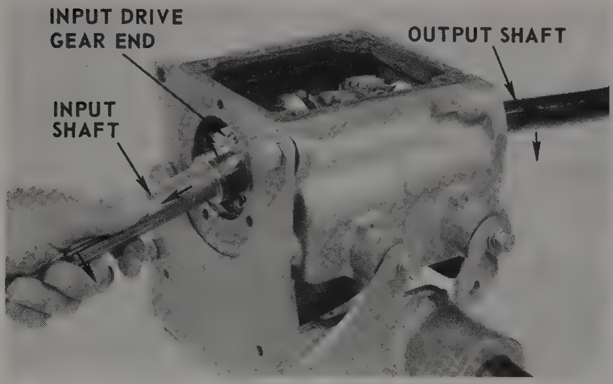

INPUT DRIVE GEAR END
OUTPUT SHAFT
INPUT SHAFT

Fig. 27-14. Removing input shaft following bearing removal. Move input and output shafts in direction of arrows to free input shaft.

of chipping or flaking. Check the condition of the roller bearing contact surface in the end of the shaft.

The blocking ring (shift cone) contact surface must be true and smooth.

Examine the bearing for wear or other damage. The bearing contact surface on the shaft must be of full diameter with no sign of wear caused by the inner race turning on the shaft.

Fig. 27-15 shows the various areas and parts of the input shaft that require inspection.

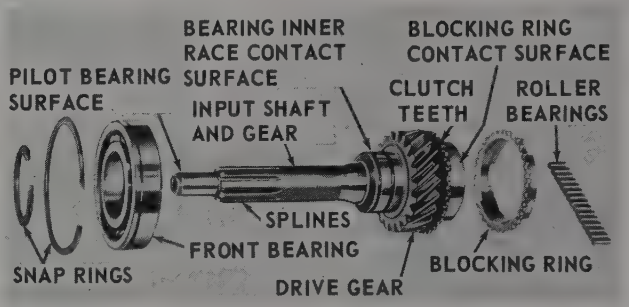

BEARING INNER RACE CONTACT SURFACE
BLOCKING RING CONTACT SURFACE
PILOT BEARING SURFACE
INPUT SHAFT AND GEAR
CLUTCH TEETH
ROLLER BEARINGS
SPLINES
FRONT BEARING
SNAP RINGS
DRIVE GEAR
BLOCKING RING

Fig. 27-15. Check these areas and parts of input shaft assembly. (Ford)

REPLACE INPUT SHAFT BEARING RETAINER OIL SEAL

Remove the bearing retainer oil seal, Fig. 27-16. Wipe a coat of sealer around the outside of the new seal and drive into place – SQUARELY, TO THE PROPER DEPTH and with the seal lip FACING THE TRANSMISSION.

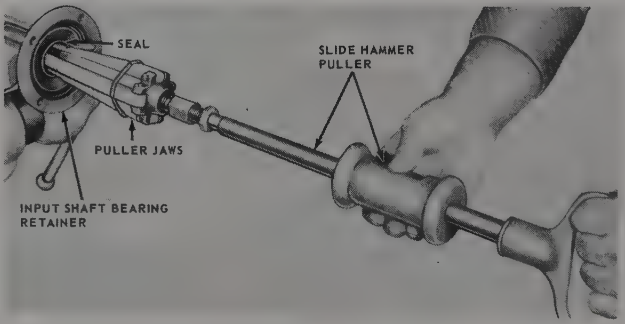

SEAL
SLIDE HAMMER PULLER
PULLER JAWS
INPUT SHAFT BEARING RETAINER

Fig. 27-16. Removing bearing retainer oil seal.

EXTENSION HOUSING

Remove the speedometer drive shaft. Remove the housing-to-case fasteners. On some transmissions, the housing may now be tapped backward until free and then removed. Another setup allows the output shaft to be removed at the same time.

The housing on the four speed transmission in Fig. 27-17 requires that the lock pin be driven from the reverse shifter lever boss. The shifter shaft is then pulled outward about 1/8 in. (3.18 mm) to disengage the shift fork from the reverse gear.

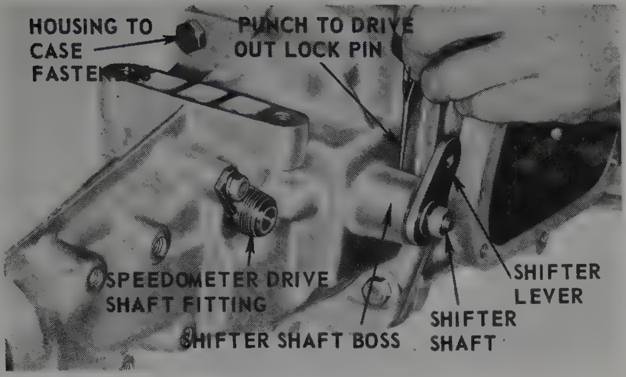

HOUSING TO CASE FASTENERS
PUNCH TO DRIVE OUT LOCK PIN
SPEEDOMETER DRIVE SHAFT FITTING
SHIFTER LEVER
SHIFTER SHAFT
SHIFTER SHAFT BOSS

Fig. 27-17. Driving out reverse shifter shaft lock pin on a four speed transmission. (Chevrolet)

The housing fasteners are then removed (speedometer drive shaft already removed). Tap the housing backward. When clear of the idler gear shaft, force the housing to the left far enough to insure the reverse shift fork clearing the reverse gear. Shaft may then be removed, Fig. 27-18.

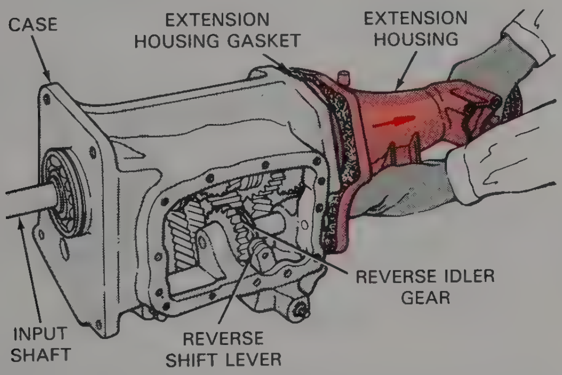

CASE
EXTENSION HOUSING GASKET
EXTENSION HOUSING
REVERSE IDLER GEAR
INPUT SHAFT
REVERSE SHIFT LEVER

Fig. 27-18. Removing extension housing. (Chrysler)

Remove the housing rear oil seal, Fig. 27-19. If worn, also remove the bushing. Clean the housing.

Drive in new bushing if required. Coat the outer edge of the new oil seal with sealer. Drive the seal into the housing SQUARELY, to the PROPER DEPTH and with the seal lip FACING INWARD. Refer to Fig. 27-20.

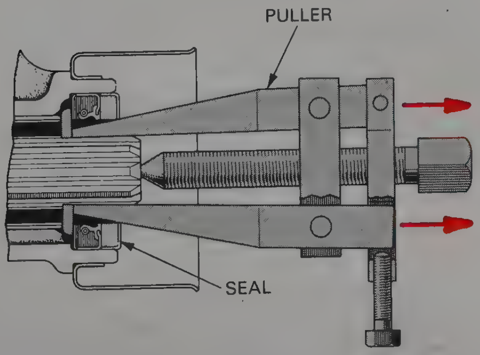

PULLER
SEAL

Fig. 27-19. Removing extension housing oil seal with a special puller. (Toyota)

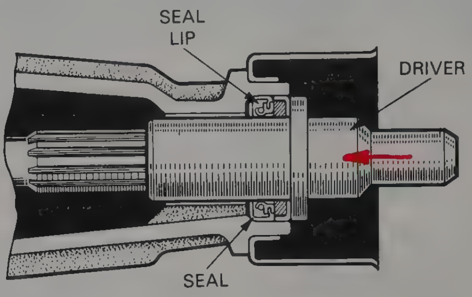

SEAL LIP
DRIVER
SEAL

Fig. 27-20. Installing new oil seal. Note seal lip is facing inward. (Toyota)

OUTPUT SHAFT

Remove the speedometer drive gear, Fig. 27-21.

Some output shafts will pull out of the transmission case complete with gears and synchronizers. Others require removal of the gears first.

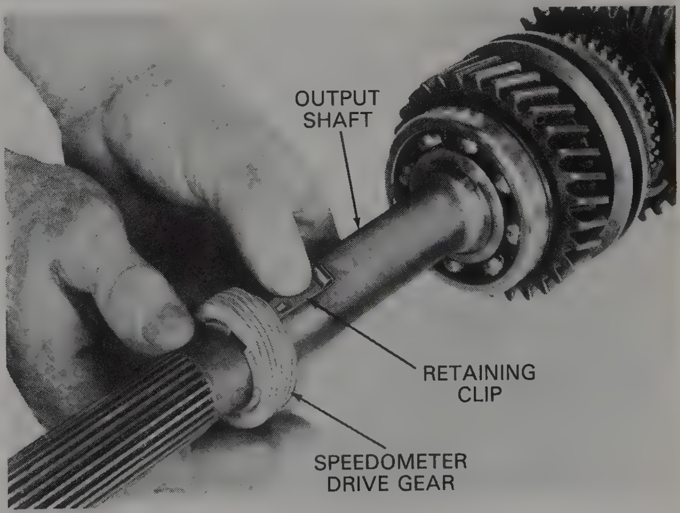

OUTPUT SHAFT
RETAINING CLIP
SPEEDOMETER DRIVE GEAR

Fig. 27-21. Removing speedometer drive gear. Some gears require use of a puller. (Oldsmobile)

If the gears must be withdrawn first, remove the snap ring (some units employ a staked nut or a detent pin) from the inboard end of the shaft, Figs. 27-22 and 27-23.

When the snap ring is removed, slide the snychronizer unit and gears from the shaft. Withdraw shaft, Fig. 27-24.

Some output shafts utilize two or more snap rings

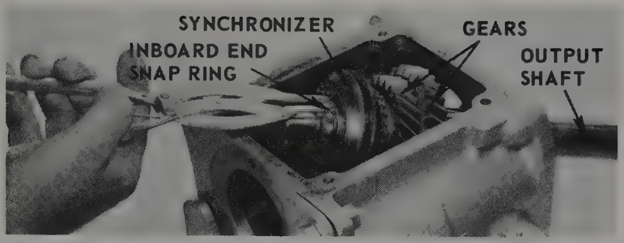

SYNCHRONIZER
GEARS
INBOARD END SNAP RING
OUTPUT SHAFT

Fig. 27-22. Removing inboard end snap ring so gears and synchronizer unit may be pulled from output shaft. (American Motors)

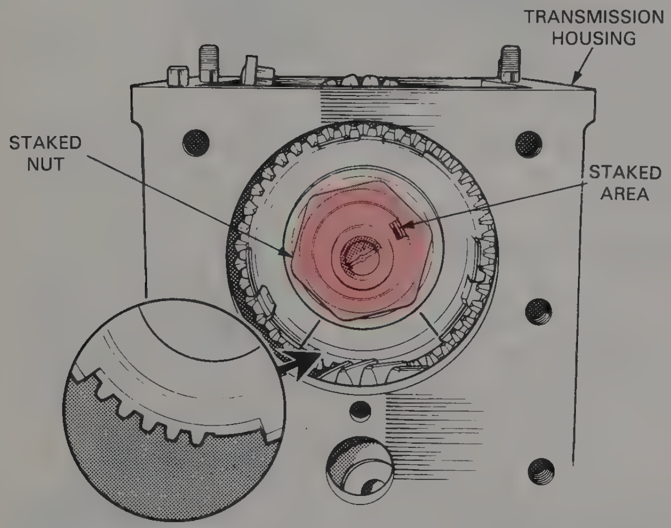

TRANSMISSION HOUSING
STAKED NUT
STAKED AREA

Fig. 27-23. Staked nut used on one particular shaft assembly. (British-Leyland)

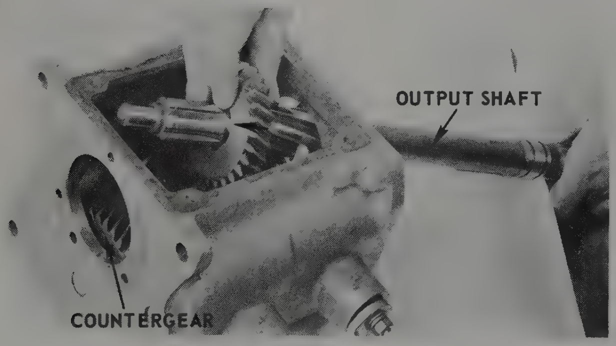

OUTPUT SHAFT
COUNTERGEAR

Fig. 27-24. Removing last gear prior to pulling output shaft.

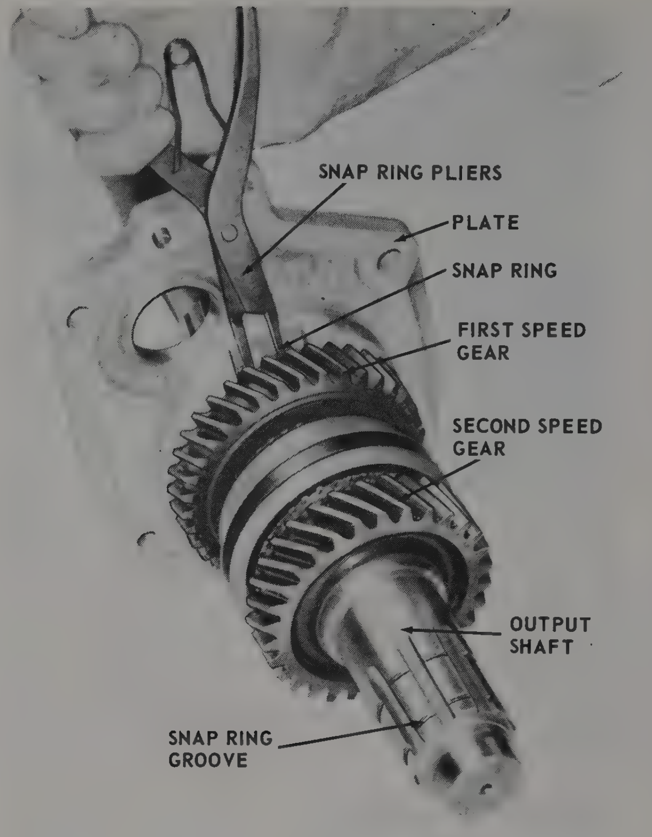

SNAP RING PLIERS
PLATE
SNAP RING
FIRST SPEED GEAR
SECOND SPEED GEAR
OUTPUT SHAFT
SNAP RING GROOVE

Fig. 27-25. Spreading output shaft rear bearing retainer snap ring. Note that this shaft and gears are removed as an assembly. (G.M.C.)

to position and retain various gears. Spring-loaded detents are also used occasionally.

The output shaft in Fig. 27-25 is removed as a complete assembly. The third and fourth speed synchronizer and the third speed gear have been removed. The mechanic is spreading the rear bearing retainer snap ring so that the bearing may be separated from the retainer. This will allow the first speed gear to slip from the shaft. The second speed gear and synchronizer may then be pulled by removing another snap ring. Disassemble and clean the output shaft assembly.

OUTPUT SHAFT AND GEAR INSPECTION

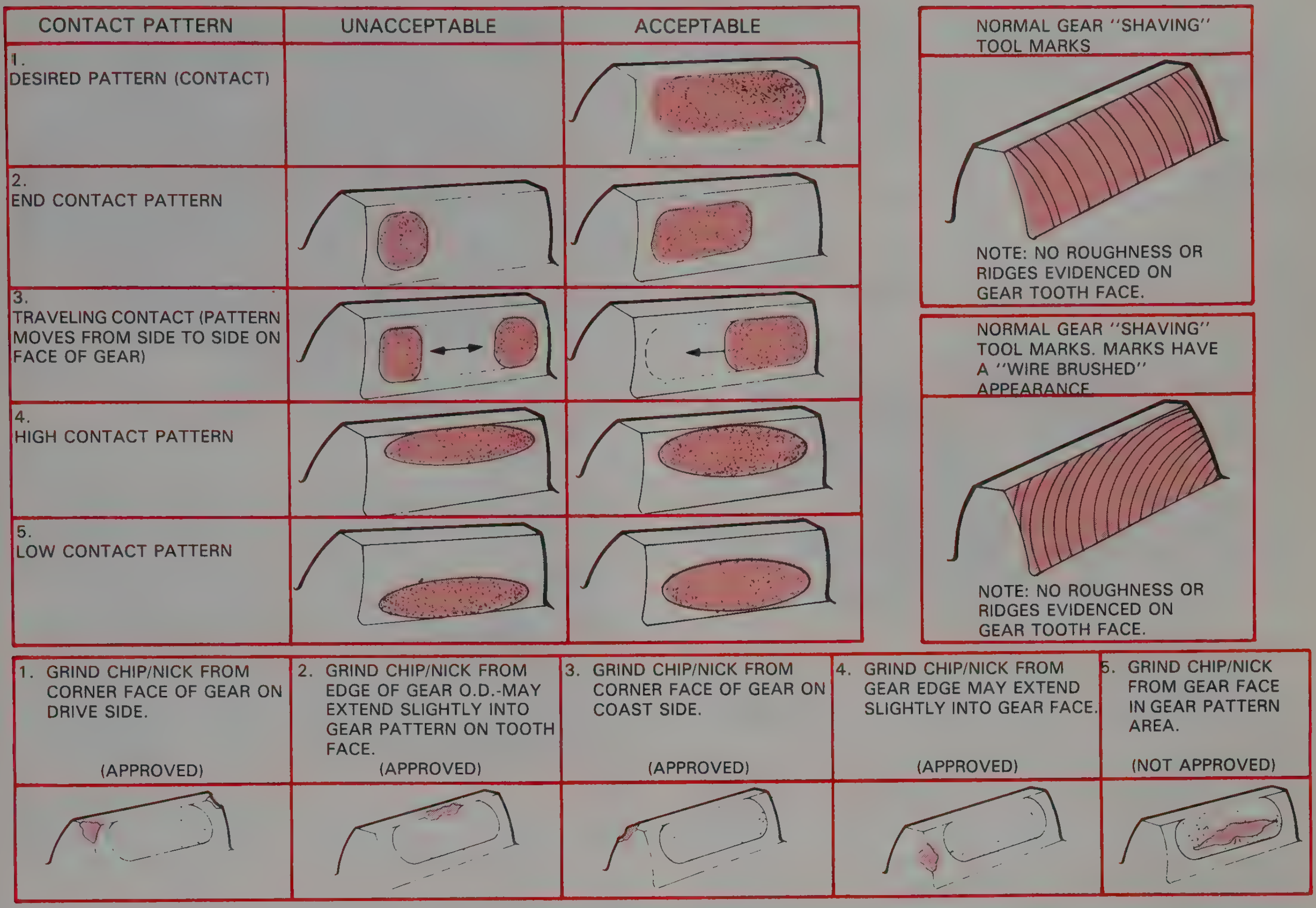
Inspect the output shaft bearing surfaces. They should be mirror smooth with no evidence of galling. Try the gears on the shaft. They should turn smoothly without excessive rocking. Where gears are splined, check for excessive play.

Look over EVERY TOOTH ON EVERY GEAR. There must be no signs of chipping, galling, or wear. If the gear has a blocking ring surface, it must be smooth. Look at Fig. 27-26.

Check the inboard pilot bearing surface of the shaft. This must be mirror smooth.

All snap ring grooves must have sharp square shoulders. Thrust washers must be smooth. Thickness must meet specifications. Inspect the output shaft rear bearing. The outboard (U-joint end) splines should be in good condition. Synchronizer inspection will be covered later in this chapter. A typical output shaft assembly is shown in Fig. 27-27.

It is good practice to check the shafts (input and/or output) for runout with a dial indicator. The shaft assembly should be supported on each end with V-blocks. The dial indicator is placed against the shaft



CONTACT PATTERN	UNACCEPTABLE	ACCEPTABLE
1. DESIRED PATTERN (CONTACT)		
2. END CONTACT PATTERN		
3. TRAVELING CONTACT (PATTERN MOVES FROM SIDE TO SIDE ON FACE OF GEAR)		
4. HIGH CONTACT PATTERN		
5. LOW CONTACT PATTERN		

NORMAL GEAR "SHAVING" TOOL MARKS

NOTE: NO ROUGHNESS OR RIDGES EVIDENCED ON GEAR TOOTH FACE.

NORMAL GEAR "SHAVING" TOOL MARKS. MARKS HAVE A "WIRE BRUSHED" APPEARANCE

NOTE: NO ROUGHNESS OR RIDGES EVIDENCED ON GEAR TOOTH FACE.

1. GRIND CHIP/NICK FROM CORNER FACE OF GEAR ON DRIVE SIDE.	2. GRIND CHIP/NICK FROM EDGE OF GEAR O.D.-MAY EXTEND SLIGHTLY INTO GEAR PATTERN ON TOOTH FACE.	3. GRIND CHIP/NICK FROM CORNER FACE OF GEAR ON COAST SIDE.	4. GRIND CHIP/NICK FROM GEAR EDGE MAY EXTEND SLIGHTLY INTO GEAR FACE.	5. GRIND CHIP/NICK FROM GEAR FACE IN GEAR PATTERN AREA.
(APPROVED)	(APPROVED)	(APPROVED)	(APPROVED)	(NOT APPROVED)

Fig. 27-26. Manual transmission-transaxle gear tooth wear patterns for one manufacturer. Study carefully. (Ford)

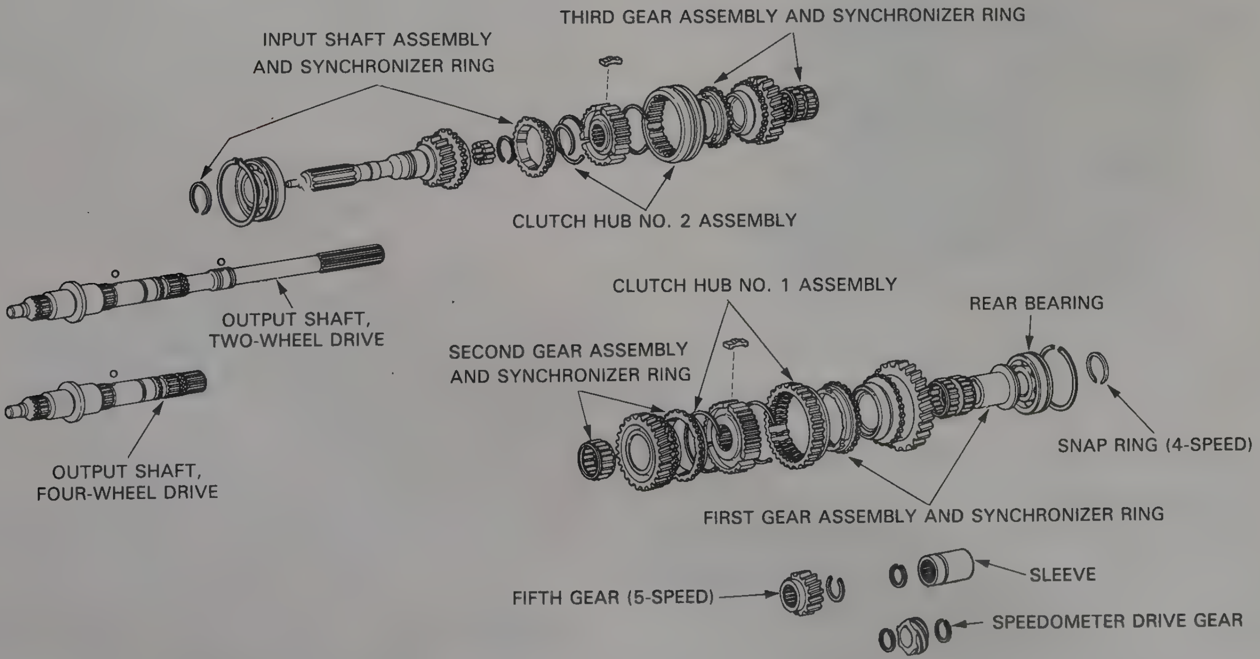

THIRD GEAR ASSEMBLY AND SYNCHRONIZER RING
INPUT SHAFT ASSEMBLY AND SYNCHRONIZER RING
CLUTCH HUB NO. 2 ASSEMBLY
OUTPUT SHAFT, TWO-WHEEL DRIVE
CLUTCH HUB NO. 1 ASSEMBLY
REAR BEARING
SECOND GEAR ASSEMBLY AND SYNCHRONIZER RING
OUTPUT SHAFT, FOUR-WHEEL DRIVE
SNAP RING (4-SPEED)
FIRST GEAR ASSEMBLY AND SYNCHRONIZER RING
SLEEVE
FIFTH GEAR (5-SPEED)
SPEEDOMETER DRIVE GEAR

Fig. 27-27. Exploded view of an output shaft assembly. Note difference between two-wheel and four-wheel drive shafts. (Toyota)

at a specified point. The dial is set to zero. Shaft is then rotated (in either direction) while noting maximum runout reading on the dial. Runout should generally not exceed .002 in. (0.06 mm). Follow maker's specifications. See Fig. 27-28.

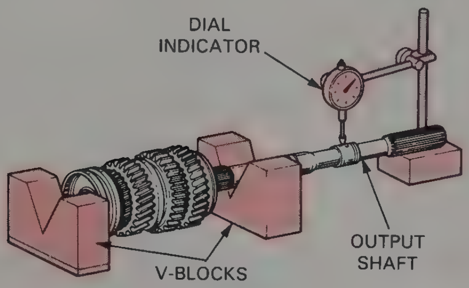

DIAL INDICATOR
OUTPUT SHAFT
V-BLOCKS

Fig. 27-28. Checking output shaft for runout with a dial indicator. Note V-blocks which accurately support shaft. (Toyota)

COUNTERSHAFT GEAR

The countershaft gear (often called cluster gear) is removed by driving out the countershaft.

The countershaft is generally secured in one of three ways. A pin (roll pin) may be driven through the case and countershaft. The pin in Fig. 27-29 is reached by removing the lubrication plug in the side of the case. Pins are sometimes accessible from the outside.

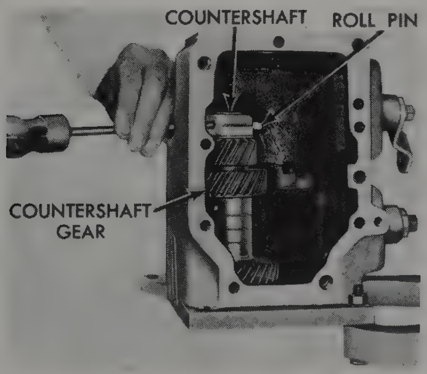

COUNTERSHAFT
ROLL PIN
COUNTERSHAFT GEAR

Fig. 27-29. Driving out countershaft roll (lock) pin.

Some pins are slightly tapered and can be driven out in one direction only.

The countershaft can be secured by a notch and flat plate. The setup in Fig. 27-30 uses a single plate to lock both the cluster gear countershaft and the reverse idler shaft. The plate is being removed.

Fig. 27-31 illustrates another method of securing the countershaft. Note that the shaft is kept from turning by a step or notch contacting a recess lip on the extension housing. The shaft cannot move to the left as it will butt against the clutch housing. Remove by driving from the front of the case.

After removing the shaft locking device, use a countershaft driver or a drift punch to drive the countershaft from the case. See Fig. 27-32.

Lift the cluster gear from the case. Clean the gear,

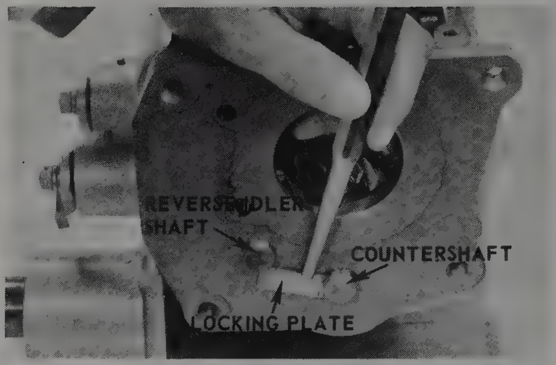

REVERSE IDLER SHAFT
COUNTERSHAFT
LOCKING PLATE

Fig. 27-30. Removing lock plate. Note that plate locks both shafts against rotation. (American Motors)

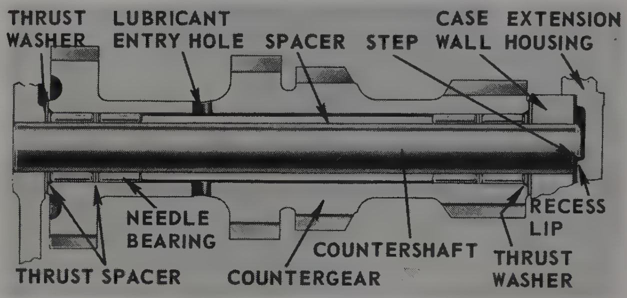

THRUST WASHER
LUBRICANT ENTRY HOLE
SPACER
STEP
CASE WALL
EXTENSION HOUSING
RECESS LIP
NEEDLE BEARING
COUNTERSHAFT
THRUST WASHER
THRUST SPACER
COUNTERGEAR

Fig. 27-31. This countershaft is secured by clutch housing and extension housing. Note center spacer and double row of needle bearings on each end. (G.M.C.)

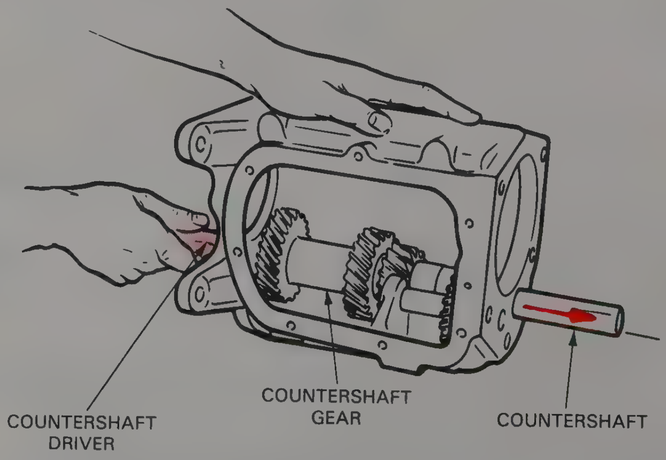

COUNTERSHAFT DRIVER
COUNTERSHAFT GEAR
COUNTERSHAFT

Fig. 27-32. Forcing countershaft from case with a driver. (G.M.C.)

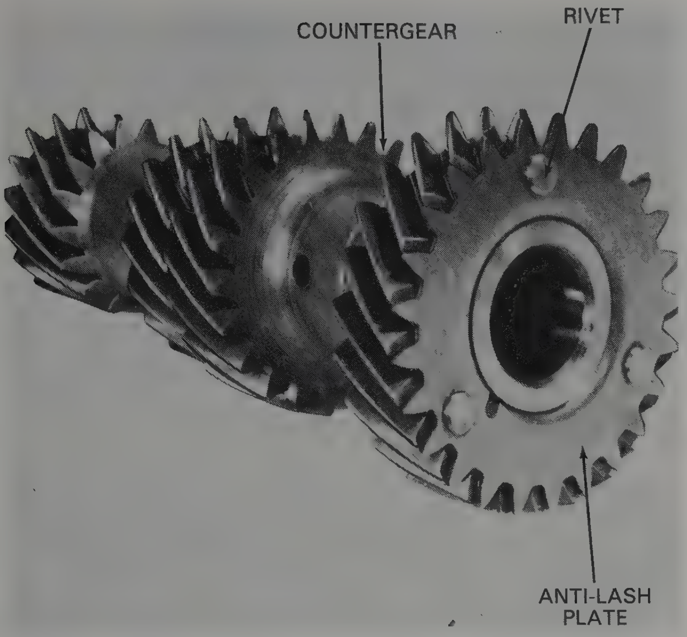

COUNTERGEAR
RIVET
ANTI-LASH PLATE

Fig. 27-33. Countergear antilash plate. This plate and gear must be replaced as a unit. (Oldsmobile)

shaft, needle bearings, thrust washers, and other parts. Inspect the gear teeth. Examine the needle bearings and countershaft. Check thrust washers, spacers, and retainer washers.

If the countergear is equipped with an antilash plate (prevents normal backlash from causing rattle), check the teeth and springs. The antilash plate in Fig. 27-33 is riveted to the countergear and should not be removed. Gear and plate replace as a unit. Some antilash plates are removable.

One type of cluster gear assembly is illustrated in Fig. 27-34.

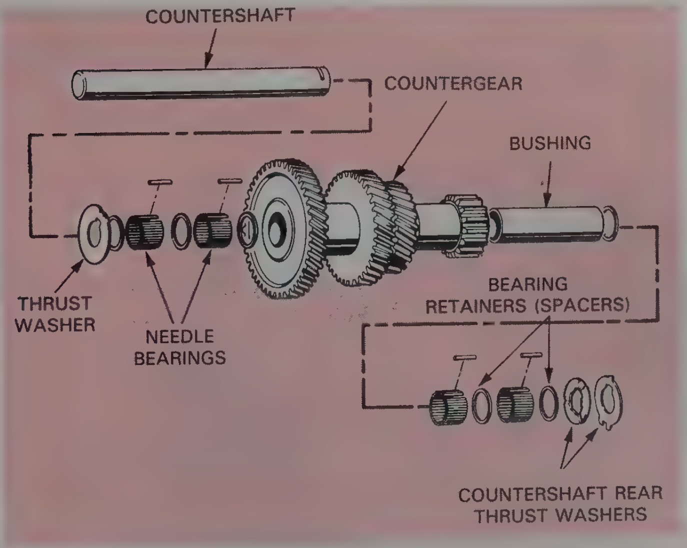

COUNTERSHAFT
COUNTERGEAR
BUSHING
THRUST WASHER
NEEDLE BEARINGS
BEARING RETAINERS (SPACERS)
COUNTERSHAFT REAR THRUST WASHERS

Fig. 27-34. Typical countergear (cluster gear), shaft, and bearings. (Jeep)

REVERSE IDLER GEAR

Drive out the reverse idler shaft locking (roll) pin (or plate in some instances).

One form of locking pin is accessible from the outside of the case. To remove, the pin is driven in until it is in the shaft. The shaft may then be drifted (driven) out.

Drift the reverse idler shaft free of the case and remove the reverse idler gear and thrust washers, Fig. 27-35.

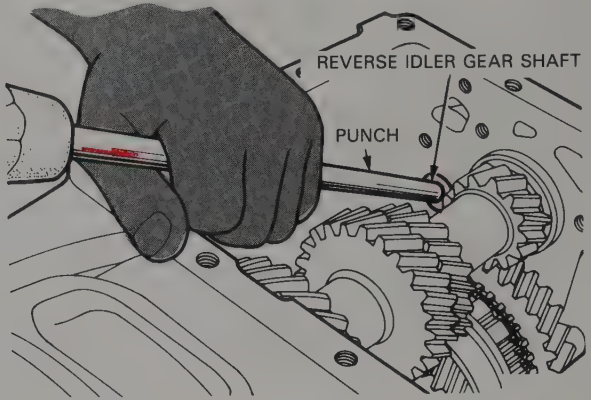

REVERSE IDLER GEAR SHAFT
PUNCH

Fig. 27-35. Using a long drift punch to drive out reverse idler gear shaft. Do not damage case or shaft with punch. (Dodge)

Clean all parts. Examine the reverse idler shaft. Inspect the idler gear bushings (some installations employ needle bearings) and thrust washers. Check the gear teeth carefully. Try the gear on the shaft and test for wear.

A reverse idler gear unit is shown in Fig. 27-36.

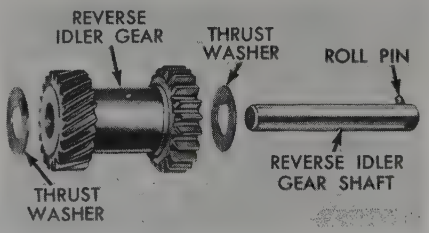

REVERSE IDLER GEAR
THRUST WASHER
ROLL PIN
THRUST WASHER
REVERSE IDLER GEAR SHAFT

Fig. 27-36. One type of reverse idler gear assembly. This gear uses bronze bushings.

SYNCHRONIZER INSPECTION AND ASSEMBLY

Scribe (mark) each blocking ring and the hub so that rings may be returned to their original side. If the clutch sleeve and hub are not marked, Fig. 27-37, scribe them so that the sleeve and hub may be reassembled in the same position.

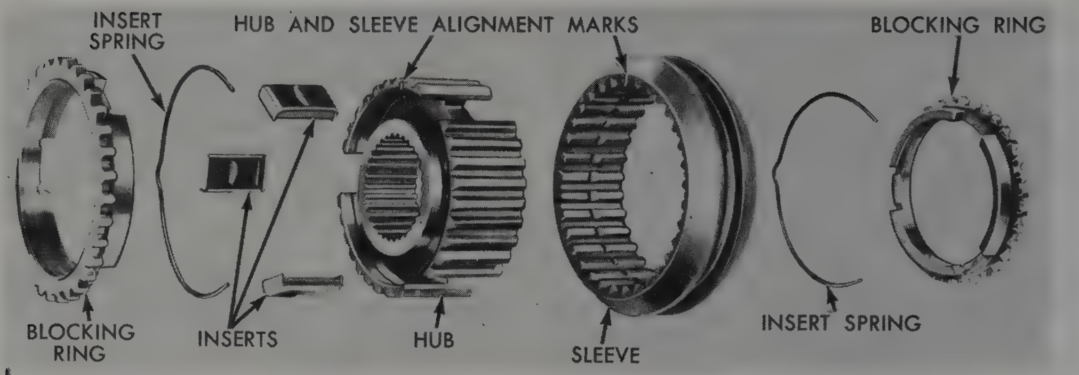

INSERT SPRING
HUB AND SLEEVE ALIGNMENT MARKS
BLOCKING RING
BLOCKING RING
INSERTS
HUB
SLEEVE
INSERT SPRING

Fig. 27-37. Synchronizer disassembled. Note alignment marks on sleeve and hub.

Slide the clutch sleeve from the clutch hub. Remove the inserts and insert springs. Clean all parts.

Fig. 27-37 shows a widely used type of synchronizer.

Check the inserts and insert springs for excessive wear. Slide sleeve on hub (marks aligned) and test play. Inspect hub inner splines. Sleeve clutch teeth must not be battered or tapered.

Pay particular attention to the blocking rings. The inside should still show fine grooves and the teeth should be in good shape. The notched sections (that fit over inserts) should not be battered and worn.

The cone surface of the gears engaged by the synchronizer should be smooth. Fig. 27-38 shows a synchronizer clutch sleeve (inserts and springs are shown—hub is not shown), blocking rings, and the two gears served by the synchronizer. Note the smooth gear cone surfaces and the grooves in the inner section of the blocking rings.

ASSEMBLYING SYNCHRONIZER

To assemble the synchronizer shown in Fig. 27-37, lubricate with transmission lube. Place one of the insert springs in the hub so that humped portion rests in one of the hub insert slots.

Align the hub and sleeve marks and start the sleeve on the hub. Be sure the sleeve is facing in the correct direction.

Install the three inserts and push the sleeve into place. Install the second spring in exactly the same manner as the first but on the opposite side of the hub. Make certain clutch sleeve and hub marks are aligned and that the insert springs are securely in place behind the lips or tabs on the ends of the inserts. Place each blocking ring into place.

Insert spring installation varies. Follow manufacturer's instructions. Note how the springs are installed in Fig. 27-39. The bent tip on each spring is installed in a different insert.

Some synchronizers are easily installed by placing the springs in the hub, installing the inserts, and then placing a compressing tool around the hub. This holds the inserts down so that the hub can be installed. Refer to Fig. 27-40.

CHECK CASE AND EXTENSION FOR CRACKS AND BURRS

Inspect the front bearing retainer, transmission case, and extension housing for signs of cracking. Look care-

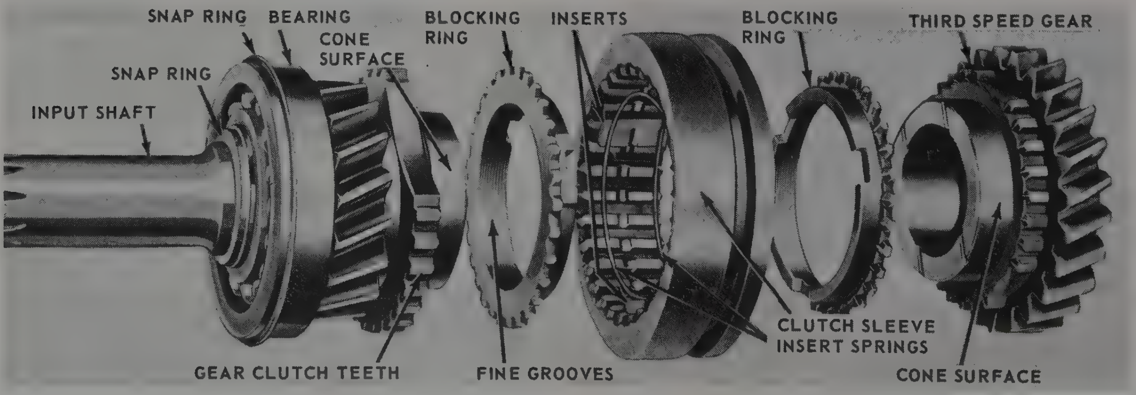

SNAP RING
BEARING
CONE SURFACE
BLOCKING RING
INSERTS
BLOCKING RING
THIRD SPEED GEAR
SNAP RING
INPUT SHAFT
CLUTCH SLEEVE
INSERT SPRINGS
GEAR CLUTCH TEETH
FINE GROOVES
CONE SURFACE

Fig. 27-38. Synchronizer (minus hub) and gears it serves. (G.M.C.)

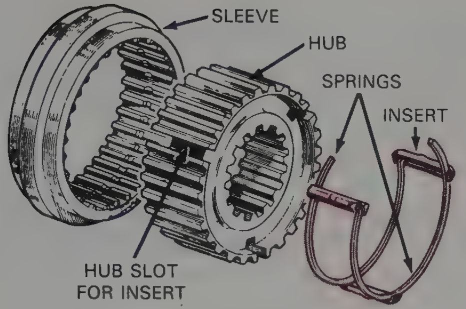

SLEEVE
HUB
SPRINGS
INSERT
HUB SLOT FOR INSERT

Fig. 27-39. Correct position of insert springs in this particular installation. When installed, the springs are inside the hub, one on each end, with inserts in hub slots.

fully, especially around bolt holes and shaft and bearing openings.

On aluminum cases, check for porous areas (slight flaws in aluminum when cast) which allow gear lubricant to seep to the outside. Follow transmission makers recommendations for repair.

Check the extension-to-case and the case-to-clutch housing surfaces for any burrs that could cause misalignment. If any are found, remove with a fine mill file. Look at Fig. 27-41.

If the transmission has a vent, make sure it is open.

TRANSMISSION ASSEMBLY

Basically, the transmission is assembled in the reverse order of disassembly. All parts must be lubricated, properly positioned, and secured before installation.

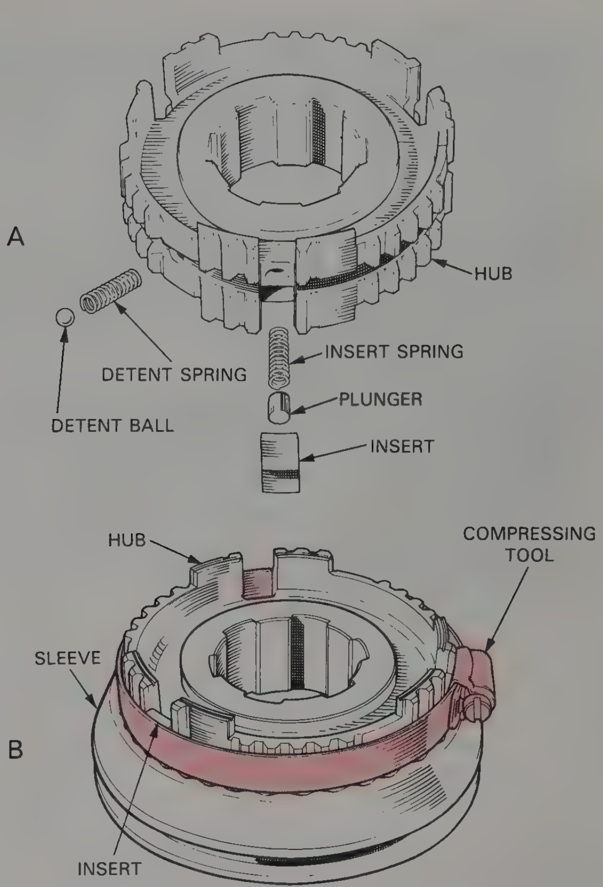

A
HUB
DETENT SPRING
INSERT SPRING
PLUNGER
DETENT BALL
INSERT
HUB
COMPRESSING TOOL
SLEEVE
B
INSERT

Fig. 27-40. A—Synchronizer hub with insert spring, insert plunger, and insert. Note detent ball and spring. B—Compressing tool being used to secure insert and detent assemblies while hub is slipped into sleeve. (British-Leyland)

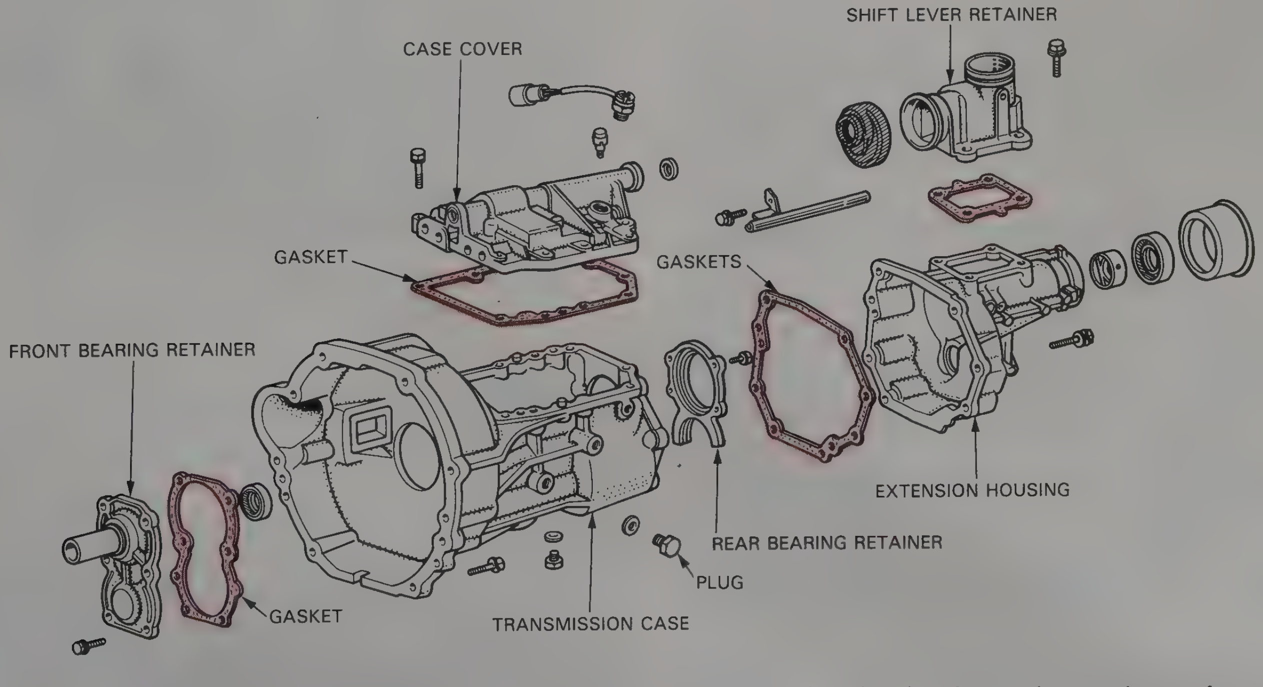

SHIFT LEVER RETAINER
CASE COVER
GASKET
GASKETS
FRONT BEARING RETAINER
EXTENSION HOUSING
REAR BEARING RETAINER
PLUG
GASKET
TRANSMISSION CASE

Fig. 27-41. Transmission case and gasket assembly. Check case, extension housing, bearing retainer, and cover for cracking, porosity, and any other damage. (Toyota)

Never use excessive force to MAKE a part fit. If some part does not slide into position as it should, stop and check for the source of difficulty. Some important installation and assembly points follow.

CHECK NEW PARTS

When a part is unfit for service, check the new part against the old for design, size, and shape. Try the part in the transmission to MAKE SURE IT FITS PROPERLY.

USE NEW SNAP RINGS, THRUST WASHERS, AND GASKETS

Good practice calls for the use of new snap rings whenever available. New thrust washers will provide proper end play. New gaskets (use gasket cement) are a must. Some cases use RTV (room temperature vulcanizing) sealer in place of gaskets. Always use recommended sealer. An inferior seal can cause a complete loss of lubricant, leading to transmission failure. If drive-in expansion plugs were removed, install new plugs. Use sealer on them.

PARTS MUST BE ABSOLUTELY CLEAN AND WELL LUBRICATED BEFORE ASSEMBLY

Following cleaning and inspection, all parts should have been oiled and placed in clean containers. Before installation, every part should be heavily lubricated with transmission oil.

SEAL AND STAKE PINS

Where pins pass through outer wall of the case, apply sealer to the hole so that the pin will not leak oil. Drive the pin a trifle below the surface of the case and stake to prevent loosening.

WHERE HEAVY DAMAGE WAS INCURRED

When a transmission has suffered heavy gear damage (teeth shattered) use crack detection chemicals on the remaining gears. Check the shafts and shaft openings in the case also. Discard all parts showing the slightest sign of cracking. Replace the bearings.

REVERSE IDLER GEAR INSTALLATION

Lubricate the bushings and shaft with transmission oil. Place a coating of soft grease (must dissolve readily in oil) on each end of the gear. Press the thrust washers into the grease. Make sure they face in the right direction. Drop the gear into place and insert the shaft. Drive in the lock pin.

Some reverse idler gears that use bushings must be replaced when the bushings are worn. Others may be repaired by pressing in new bushings and honing.

If the reverse idler gear used needle bearings, these may be held in place with a dummy shaft (shaft same diameter as regular shaft but only as long as gear plus thrust washer thickness). When the regular shaft moves into the gear, the dummy is forced out ahead. This provides proper alignment and holds the needles, spacers, and thrust washers in line.

Note the reverse idler lock pin setup shown in Fig. 27-42. The angled hole in the shaft must align with the hole in the case. Drive the pin in as shown in A. Use sealer and stake.

To remove this shaft, the pin must be driven completely into the shaft. In that it is shorter than the shaft diameter, once in, the shaft may be driven out, Fig. 27-42.

Once the gear is in place, check for correct end play. The gear must turn freely.

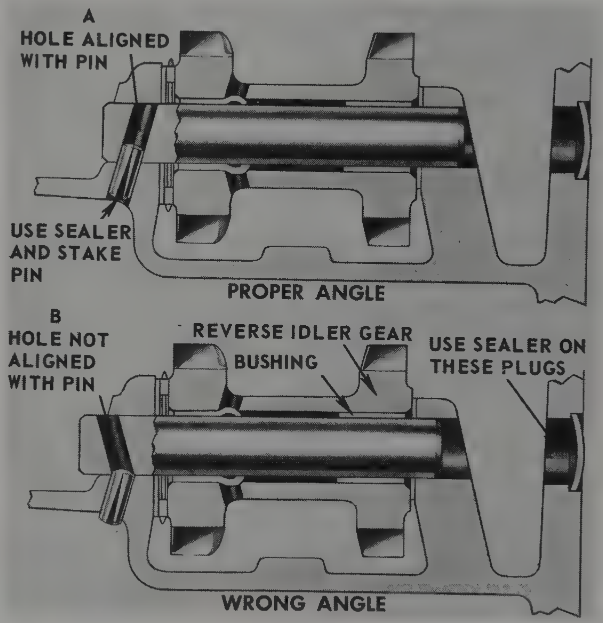


Fig. 27-42. Reverse idler gear shaft pin hole must align with pin hole in transmission case. (Chevrolet)

COUNTERGEAR INSTALLATION

Wipe the bearing bores at each end of the countergear with a generous coat of soft grease. Use a grease that will readily dissolve in the transmission oil. Do not plug the oil entry hole.

Slide a dummy shaft through the gear. Use a dummy (temporary shaft) that is the same diameter as the regular countershaft. It should protrude past the ends of the gear far enough to support the thrust washers but not so far that the assembly cannot be inserted in

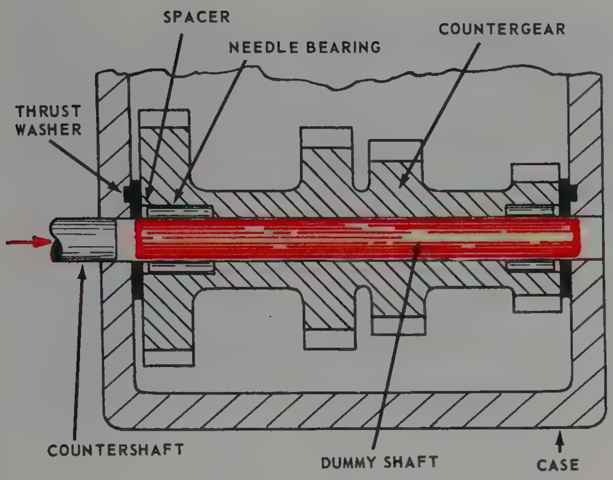

SPACER
NEEDLE BEARING
COUNTERGEAR
THRUST WASHER
COUNTERSHAFT
DUMMY SHAFT
CASE

Fig. 27-43. Dummy shaft holds the bearings, spacers, and thrust washers in line so that regular countershaft can be inserted.

the case. See Fig. 27-43.

Insert spacer, if used. Insert the needle bearings at both ends of the countergear. MAKE SURE EACH NEEDLE IS GREASED. Use the exact number of needles specified, Fig. 27-44.

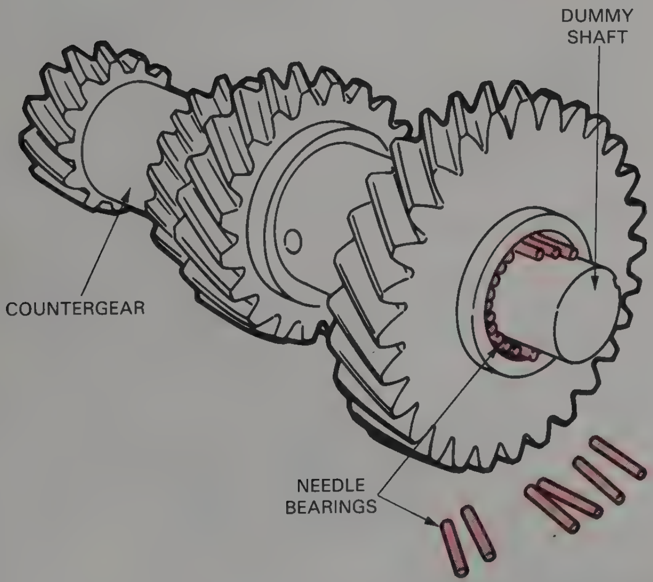

DUMMY SHAFT
COUNTERGEAR
NEEDLE BEARINGS

Fig. 27-44. Needle bearings placed in countergear. Dummy shaft holds them in position for installation. Use correct number of bearings. (G.M.C.)

Coat the ends of the gear with grease. Press the thrust washers into place, being careful that they face in the correct direction. Some have lips or dents that must align with cutouts in either the case or gear. Others have flats that must align with a corresponding lip.

Lower the gear into the case and align with the case holes. Refer to Fig. 27-45.

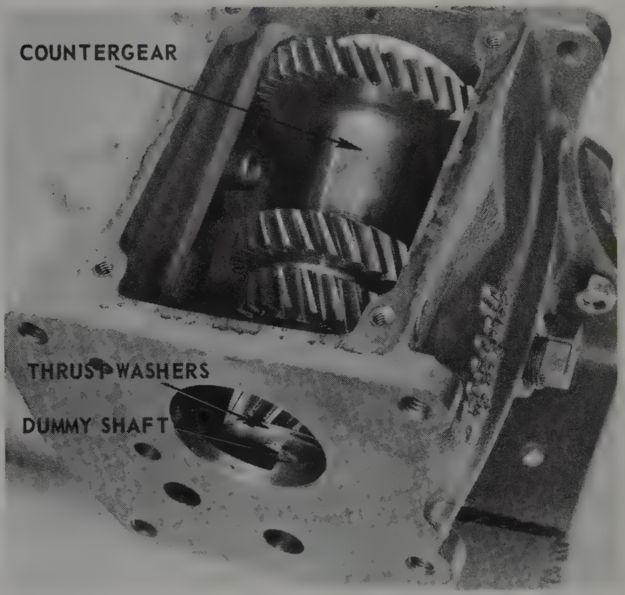

COUNTERGEAR
THRUST WASHERS
DUMMY SHAFT

Fig. 27-45. Lowering countergear into case. Note the dummy shaft. (American Motors)

Install the countershaft. As the countershaft is tapped through the gear, hold onto the dummy so it is not knocked completely out. Keep the countershaft and dummy ends together to prevent the thrust washers, or possibly the needles, from moving out of alignment. See Fig. 27-46.

Spin the countergear. It must turn freely. Check the end play with a dial indicator or with a feeler gauge, as shown in Fig. 27-47.

If the countergear must be lowered to install the output or input shaft, force the countershaft out with the dummy. Place the gear on the bottom of the case. When the countershaft is finally installed, make certain it is locked in place and when required, sealed.

INPUT AND OUTPUT SHAFT INSTALLATION

Coat the roller bearing surface in the end of the input shaft with soft grease. Do not plug the oil entry

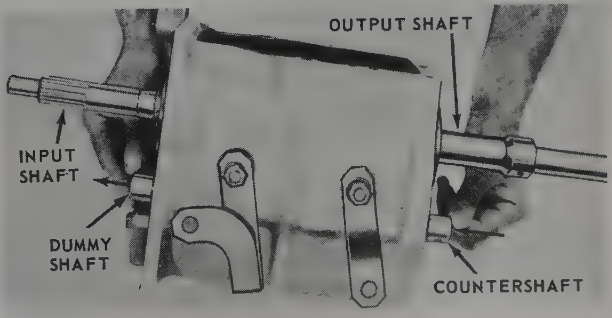

OUTPUT SHAFT
INPUT SHAFT
DUMMY SHAFT
COUNTERSHAFT

Fig. 27-46. Installing countershaft. As countershaft is moved into position, the dummy is forced out of case.

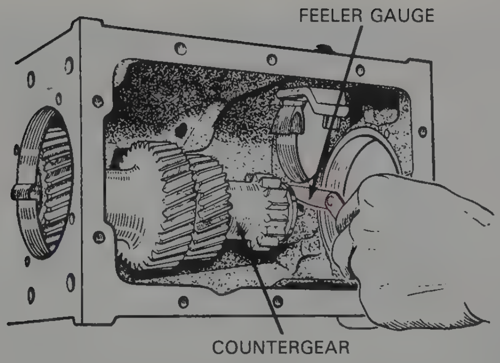


Fig. 27-47. Checking countergear end play with feeler gauge. (British-Leyland)

hole. Install the exact number of rollers specified. Install a snap ring if required, Fig. 27-48.

Install the gears, snap rings, and synchronizer units on the output shaft (shaft may have to be inserted into case first). Lubricate each part with gear oil before assembly. Make certain the snap rings are fully seated. Be sure that the gears and synchronizers face in the proper direction. Blocking rings must be in place.

Install both shafts in the reverse order of disassembly.

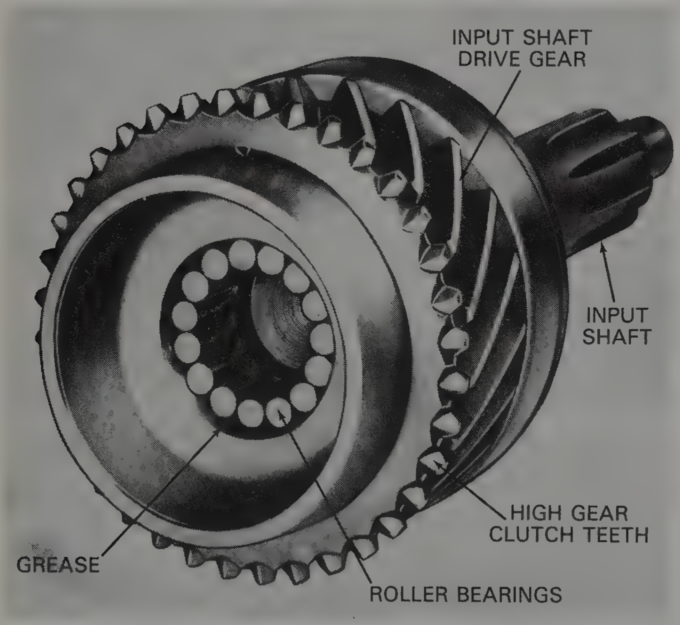


Fig. 27-48. Coating of soft grease used to hold roller bearings in place. (Oldsmobile)

Fig. 27-49 shows a mechanic installing the input shaft. Great care must be taken to avoid disturbing the rollers. When input and output are mated, do not let them separate. This may cause the rollers to dislodge and drop into the case.

Install extension housing and input bearing retainer.

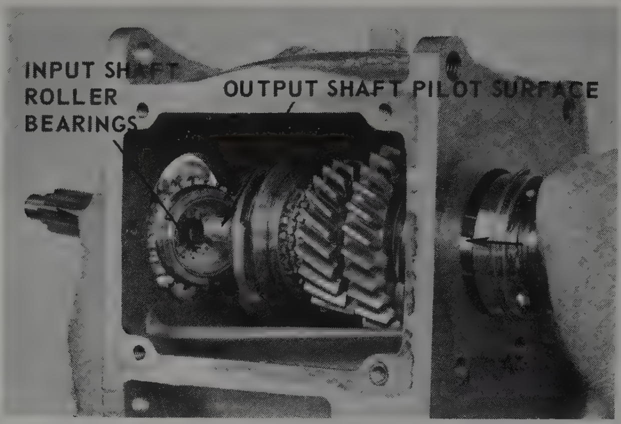


Fig. 27-49. Installing input shaft. Output shaft pilot must be carefully guided into input roller bearing. Once mated, do not pull apart.

Torque the fasteners. When any fasteners pass through and into the case, place some sealer on the threads to prevent leaks. Fasteners must be of the correct length to avoid passing into the case and striking a moving part.

WHEN FULLY ASSEMBLED

When the transmission is fully assembled (except for cover), pour fresh gear oil over the gears and shaft. Use recommended oil viscosity.

Turn the input shaft while shifting through the gears. The shafts and gears should turn freely with no catching. Check shaft end play.

INSTALLING SHIFT COVER

To install the shift cover, place the transmission in NEUTRAL. Place the shift fork levers in the neutral position. Hold the cover in line with the cover hole. The shift forks must align with the clutch sleeve and gear fork grooves.

Using a new gasket and cement, guide the shift forks into their grooves. Insert the cover fasteners. Tighten. Try the shift mechanism for proper operation, Fig. 27-50.

TRANSMISSION INSTALLATION

Wipe clutch housing and transmission face clean. Check for burrs.

Using guide pins or a transmission jack stand, insert the transmission input shaft through the clutch throw-out bearing, disc hub, and into the pilot bearing. NEVER LET THE TRANSMISSION HANG SUPPORTED BY THE INPUT SHAFT.

Install and torque transmission-to-clutch housing and transmission support fasteners. Install drive line, speedometer cable, shift linkage, and other parts.

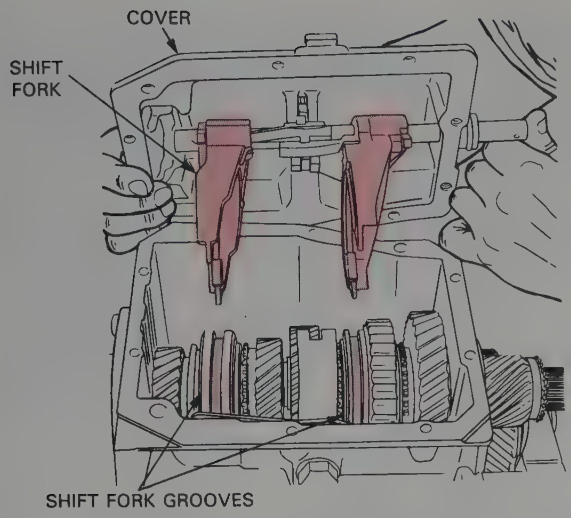

COVER
SHIFT FORK
SHIFT FORK GROOVES

Fig. 27-50. Installing shift cover. Shift forks must align with shift fork grooves. Do not force cover into position! (Chevrolet)

ADJUSTING SHIFT LINKAGE

Disconnect the shift rods at the transmission (or at column shift levers). Place the transmission shift levers in NEUTRAL.

If the linkage has slotted adjustment holes, Fig. 27-51, loosen the adjustment nuts and leave the shift rods connected.

With the transmission shift levers in NEUTRAL, place the column shift levers in NEUTRAL. It may be necessary to pass an aligning pin through the levers or to use a special tool, as shown in Fig. 27-51. Tighten the linkage adjustment nuts.

If the linkage is the type that was disconnected, adjust the linkage length so that the rods just reach from the transmission to the column shift levers. Insert and secure linkage.

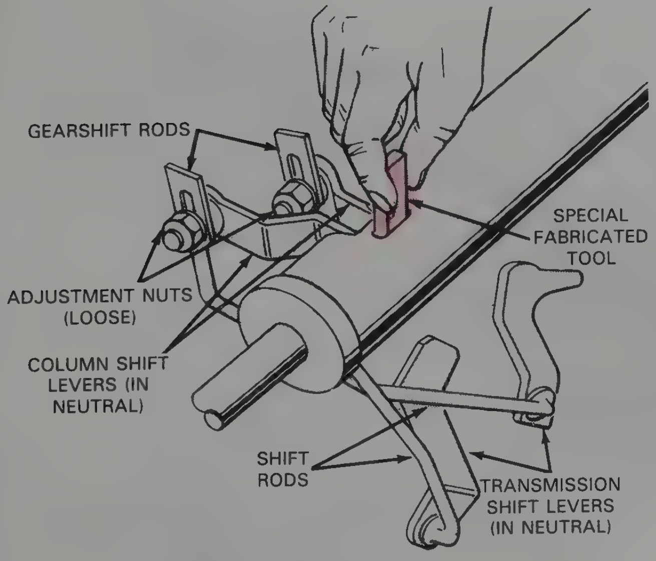

GEARSHIFT RODS
SPECIAL FABRICATED TOOL
ADJUSTMENT NUTS (LOOSE)
COLUMN SHIFT LEVERS (IN NEUTRAL)
SHIFT RODS
TRANSMISSION SHIFT LEVERS (IN NEUTRAL)

Fig. 27-51. Using special tool to hold column shift levers in neutral. When both column and transmission shift levers are in neutral, tighten adjustment nuts. (Ford)

A typical four speed transmission floor shift is illustrated in Fig. 27-52. To adjust this linkage, loosen shift linkage adjustment nuts. Place gear shift lever in neutral and pass the alignment pin through the aligning holes. Place transmission shift levers in neutral. Tighten adjustment nuts. Remove pin.

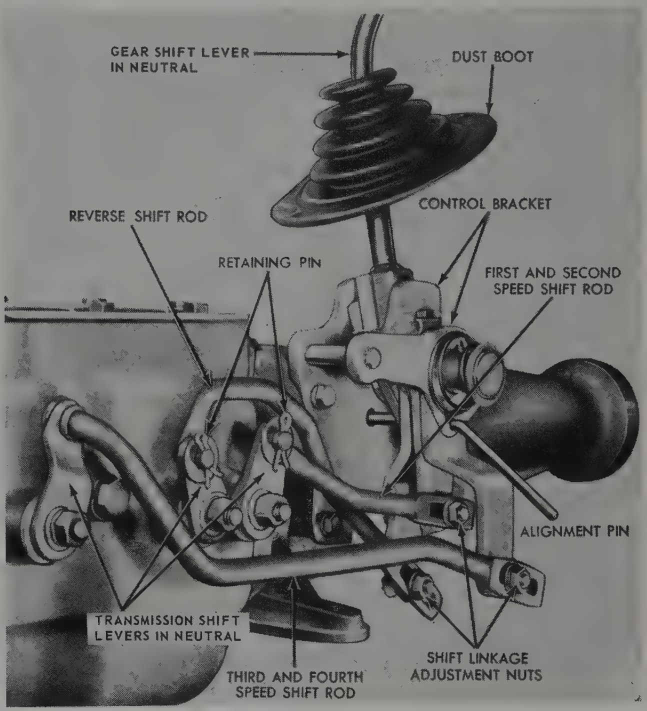

GEAR SHIFT LEVER IN NEUTRAL
DUST BOOT
REVERSE SHIFT ROD
CONTROL BRACKET
RETAINING PIN
FIRST AND SECOND SPEED SHIFT ROD
ALIGNMENT PIN
TRANSMISSION SHIFT LEVERS IN NEUTRAL
THIRD AND FOURTH SPEED SHIFT ROD
SHIFT LINKAGE ADJUSTMENT NUTS

Fig. 27-52. Adjusting shift linkage on a four speed, floor shift transmission. Note use of alignment pin to hold gearshift in neutral position.

FILL TRANSMISSION

Fill the transmission to the level of the filler plug with the recommended gear oil. Fill slowly so that the oil will have time to flow. This is especially true when the overdrive unit used is filled from the transmission. FILL THE TRANSMISSION PROPERLY WITH CLEAN GEAR OIL OF THE CORRECT VISCOSITY AND TYPE. See Fig. 27-53.

ROAD TEST

Road test the car. The transmission should operate quietly and smoothly. Shifting should be smooth and positive with no jumping out of gear. Shift up and down to test the synchronizers. When back at the shop, check for leakage. Recheck lubricant level.

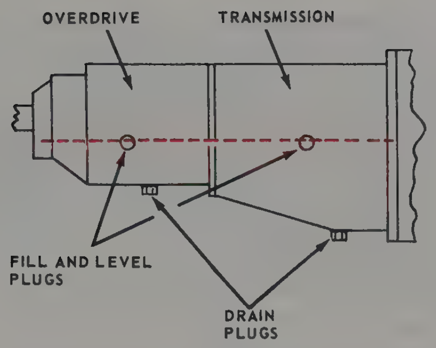

OVERDRIVE
TRANSMISSION
FILL AND LEVEL PLUGS
DRAIN PLUGS

Fig. 27-53. Where both transmission and overdrive have level plugs, bring lubricant level even with bottom of both plugs. Fill slowly so correct level is attained.

OVERDRIVE TRANSMISSION — FREEWHEELING TYPE

The freewheeling transmission overdrive, Figs. 27-54, 27-55, and 27-56, is basically a standard transmission with an overdrive unit attached to the rear. Note in Fig. 27-55 that the transmission output shaft is splined to the roller (overrunning) clutch hub and to the pinion carrier hub.

When operating in OVERDRIVE, the unit will produce a high gear ratio of around 0.7 to 1 instead of the NORMAL 1 to 1.

Fig. 27-56 shows overdrive action in DIRECT-FREEWHEELING DRIVE, OVERDRIVE, AND LOCKED-OUT DRIVE. Study the power flow.

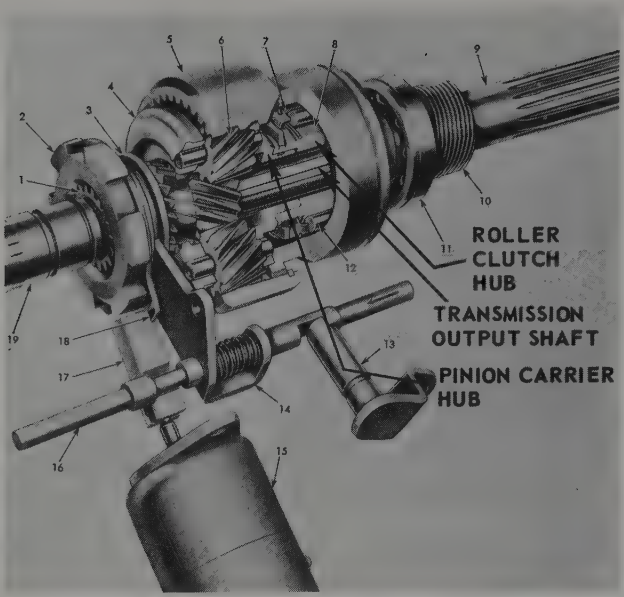

5
6
7
8
9
4
2
3
1
10
ROLLER CLUTCH HUB
11
12
TRANSMISSION OUTPUT SHAFT
13
PINION CARRIER HUB
19
18
17
14
15
16

Fig. 27-55. Detailed view of overdrive unit. 1—Sun gear teeth for balk ring gear. 2—Balk gear. 3—Sun gear shift groove. 4—Pinion carrier assembly. 5—Internal gear (ring gear). 6—Planet pinion gear. 7—Roller clutch rollers and cage. 8—Roller clutch hub. 9—Overdrive output shaft. 10—Speedometer drive gear. 11—Output shaft bearings. 12—Roller clutch roller. 13—Control lever rod. 14—Shift fork. 15—Solenoid. 16—Shift rail. 17—Pawl. 18—Balk ring. 19—Transmission output shaft. (Chevrolet)

OVERDRIVE SERVICE

On some installations, it is possible to perform repairs on the overdrive with the transmission left in

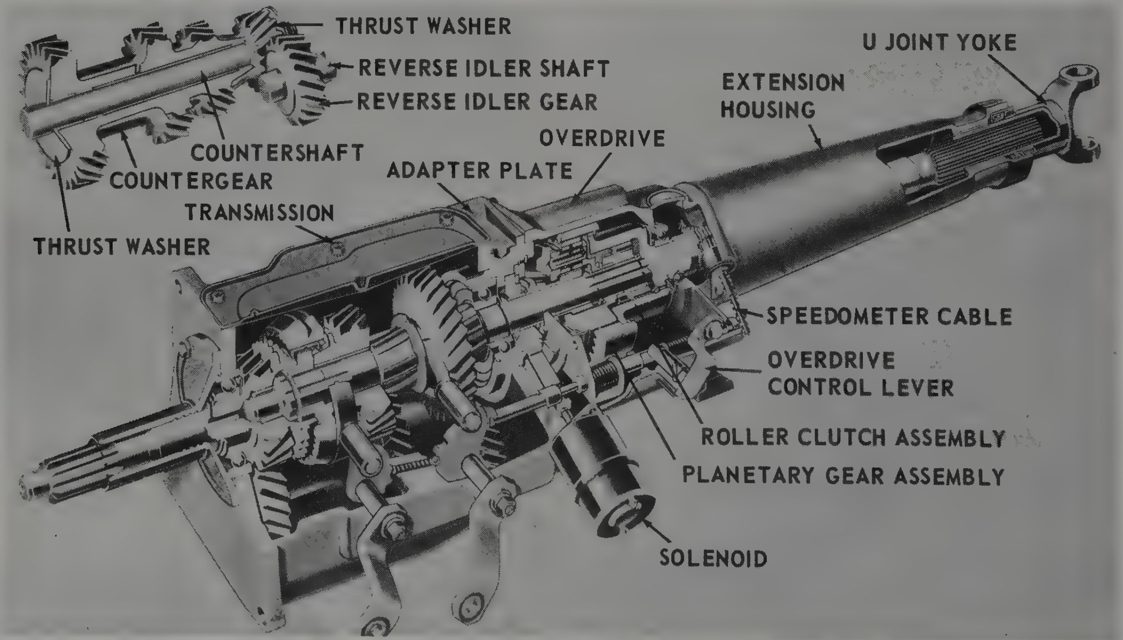

THRUST WASHER
REVERSE IDLER SHAFT
REVERSE IDLER GEAR
U JOINT YOKE
EXTENSION HOUSING
OVERDRIVE
ADAPTER PLATE
COUNTERSHAFT
COUNTERGEAR
TRANSMISSION
THRUST WASHER
SPEEDOMETER CABLE
OVERDRIVE CONTROL LEVER
ROLLER CLUTCH ASSEMBLY
PLANETARY GEAR ASSEMBLY
SOLENOID

Fig. 27-54. Cutaway view of one type of overdrive transmission. This is a three speed transmission with a planetary gear overdrive attached to the rear.

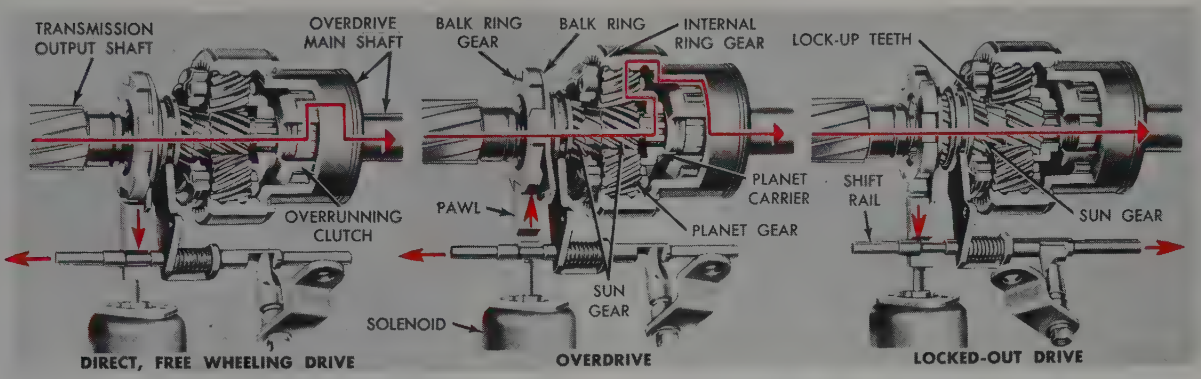

TRANSMISSION OUTPUT SHAFT
OVERDRIVE MAIN SHAFT
BALK RING GEAR
BALK RING
INTERNAL RING GEAR
LOCK-UP TEETH
OVERRUNNING CLUTCH
PAWL
PLANET CARRIER
SHIFT RAIL
SUN GEAR
PLANET GEAR
SUN GEAR
SOLENOID
DIRECT, FREE WHEELING DRIVE
OVERDRIVE
LOCKED-OUT DRIVE

Fig. 27-56. Power flow in three overdrive positions — DIRECT-FREEWHEELING, OVERDRIVE, and LOCKED-OUT DRIVE. (Ford)

the car. The propeller shaft is dropped and the overdrive unit disassembled, as described later in this chapter.

Most setups require that the transmission be removed from the car. Transmission removal procedure is the same as that described for standard transmissions.

LOOK BEFORE YOU LEAP

A great number of overdrive difficulties are due to either an improperly adjusted control cable, inoperative governor or solenoid, or some malfunction in the electrical control system. BEFORE PULLING THE TRANSMISSION AND DISASSEMBLING THE OVERDRIVE, CHECK OUT THE MECHANICAL AND ELECTRICAL CONTROLS. See the overdrive section on problem diagnosis at the end of this chapter.

A schematic of an overdrive electrical system is shown in Fig. 27-57.

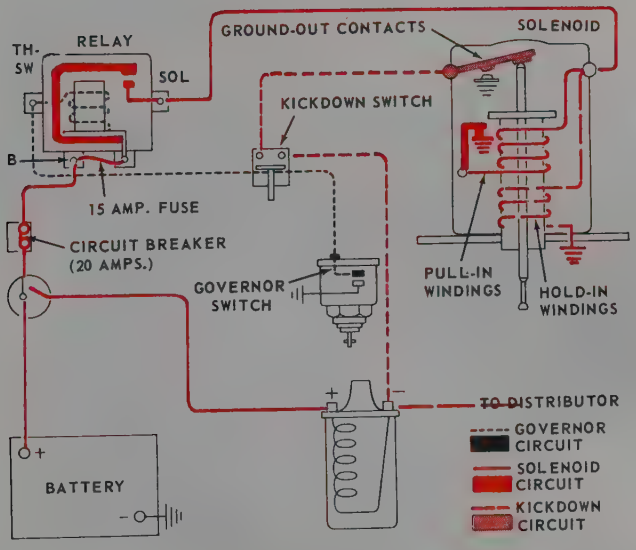

TH-SW
RELAY
SOL
B
GROUND-OUT CONTACTS
SOLENOID
KICKDOWN SWITCH
15 AMP. FUSE
CIRCUIT BREAKER (20 AMPS.)
GOVERNOR SWITCH
PULL-IN WINDINGS
HOLD-IN WINDINGS
+
−
TO DISTRIBUTOR
+
BATTERY
GOVERNOR CIRCUIT
SOLENOID CIRCUIT
KICKDOWN CIRCUIT

Fig. 27-57. Overdrive electrical control circuit. (American Motors)

OVERDRIVE DISASSEMBLY

Basically, the freewheeling types of overdrive, as used by the various car manufacturers, are similar.

Except for a few minor points, general procedures for disassembly given in the following pages apply to all.

The overdrive can be disassembled without disturbing the transmission by not allowing the adapter plate to move away from the transmission.

Place the transmission in a stand. If oil was not drained before removal from car, drain at this time.

Remove the overdrive governor and the speedometer drive shaft. Remove the overdrive-to-transmission fasteners. Drive out the overdrive shift shaft lock pin. Pull the shaft out as far as possible, Fig. 27-58.

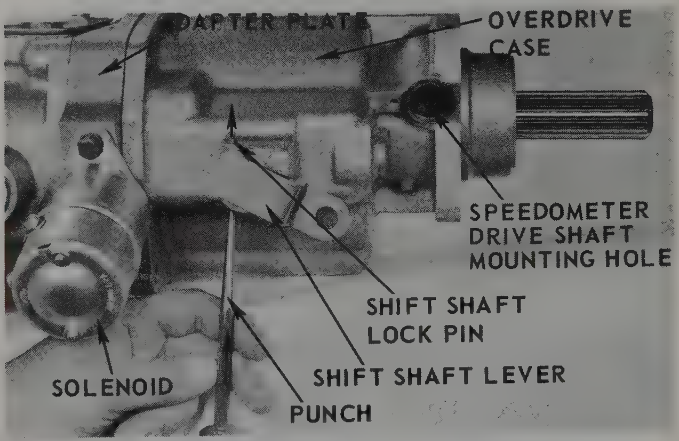

ADAPTER PLATE
OVERDRIVE CASE
SPEEDOMETER DRIVE SHAFT MOUNTING HOLE
SHIFT SHAFT LOCK PIN
SOLENOID
SHIFT SHAFT LEVER
PUNCH

Fig. 27-58. Driving out overdrive shift shaft lock pin.

If the overdrive unit has a large snap ring access hole cover at the top, pierce the plug and pry out. See Fig. 27-59.

Using snap ring pliers through the access hole, spread the overdrive output shaft bearing snap ring. While keeping the ring open, tap the shaft to force the bearing

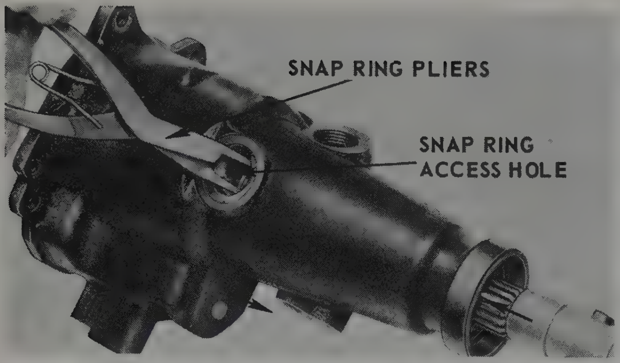

SNAP RING PLIERS
SNAP RING ACCESS HOLE

Fig. 27-59. Spreading overdrive output shaft bearing snap ring while tapping shaft to free bearing. (Chevrolet)

past the snap ring, Fig. 27-59.

The overdrive unit on one line of cars does not have the snap ring setup just described. To free the case in this setup, remove the short extension housing on the overdrive case. This will expose a snap ring on the overdrive output shaft. Remove this snap ring, Fig. 27-60.

Pull the overdrive case back while tapping the output shaft. Do not allow the adapter to move away from the transmission. To do so will allow the transmission output shaft pilot end to pull free of the rollers in the input shaft. This could allow the rollers to drop into the case, requiring transmission disassembly for removal.

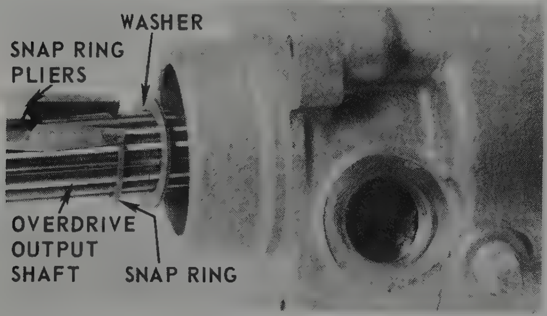

WASHER
SNAP RING PLIERS
OVERDRIVE OUTPUT SHAFT
SNAP RING

Fig. 27-60. Removing snap ring on overdrive output shaft. (American Motors)

As soon as the overdrive case has moved free of the adapter far enough to provide clearance, install a cap screw in the adapter to hold it against the transmission. Refer to Fig. 27-61.

Fig. 27-62 shows the overdrive unit with case removed.

Remove the output shaft assembly by pulling it free. Catch the clutch rollers, Fig. 27-63.

The ring gear may be removed from the output shaft by prying out the large snap ring holding the units together, Fig. 27-64.

Pry out the roller clutch cam retaining clips, Figs. 27-65 and 27-66.

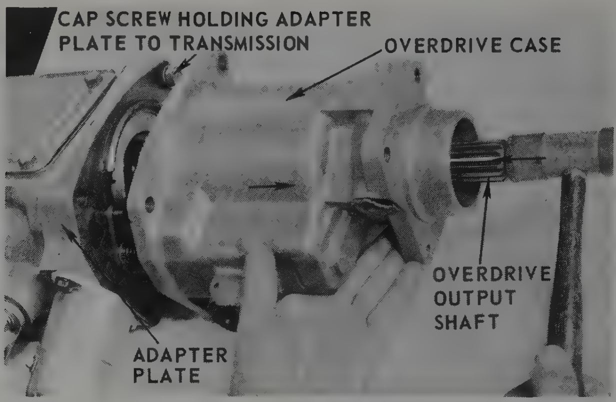

CAP SCREW HOLDING ADAPTER PLATE TO TRANSMISSION
OVERDRIVE CASE
OVERDRIVE OUTPUT SHAFT
ADAPTER PLATE

Fig. 27-61. Pulling overdrive case free while tapping output shaft inward. Note cap screw holding adapter plate to transmission.

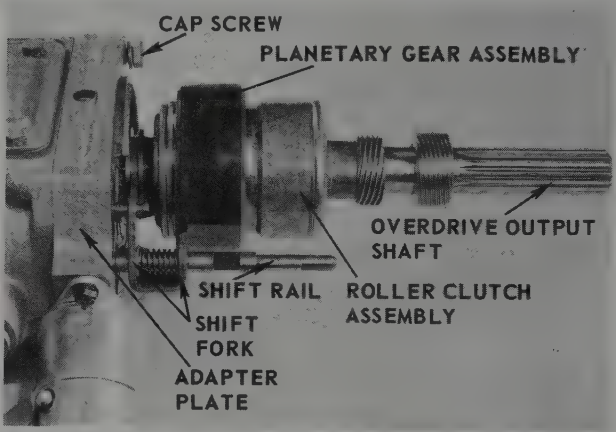

CAP SCREW
PLANETARY GEAR ASSEMBLY
OVERDRIVE OUTPUT SHAFT
SHIFT RAIL
ROLLER CLUTCH ASSEMBLY
SHIFT FORK
ADAPTER PLATE

Fig. 27-62. Overdrive with case removed. Note that adapter plate is kept against transmission with a cap screw.

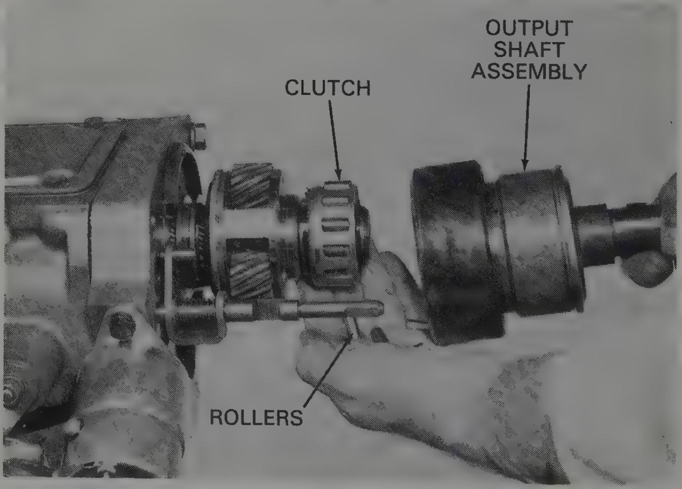

OUTPUT SHAFT ASSEMBLY
CLUTCH
ROLLERS

Fig. 27-63. Removing overdrive output shaft assembly.

Pull the roller clutch and planet carrier from the shaft, Fig. 27-67.

Slide the sun gear and shift rail assembly off the shaft

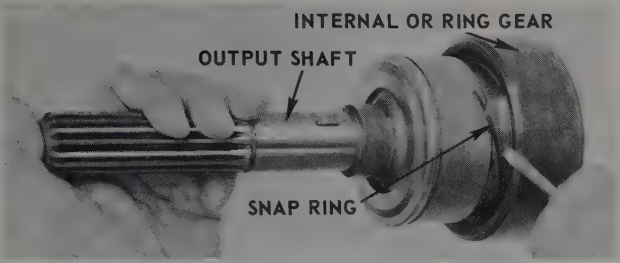

INTERNAL OR RING GEAR
OUTPUT SHAFT
SNAP RING

Fig. 27-64. Removing snap ring to free ring gear from overdrive output shaft and roller clutch outer contact ring.

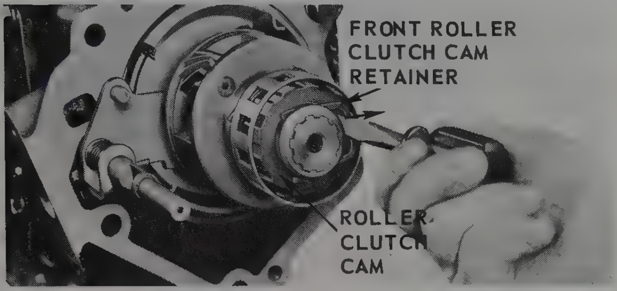

FRONT ROLLER CLUTCH CAM RETAINER
ROLLER CLUTCH CAM

Fig. 27-65. Removing front roller clutch cam retainer. (Chevrolet)

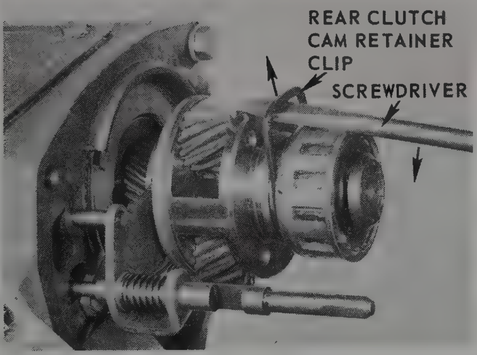

REAR CLUTCH CAM RETAINER CLIP
SCREWDRIVER

Fig. 27-66. Removing rear roller clutch cam retainer. (American Motors)

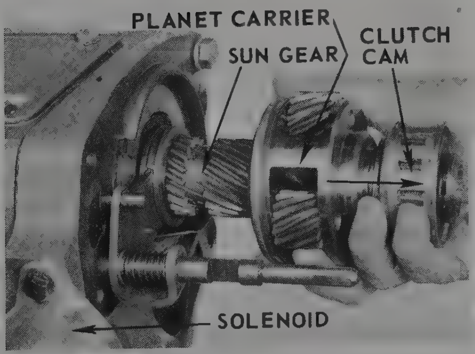

PLANET CARRIER
SUN GEAR
CLUTCH CAM
SOLENOID

Fig. 27-67. Pulling clutch cam and planet carrier from transmission output shaft.

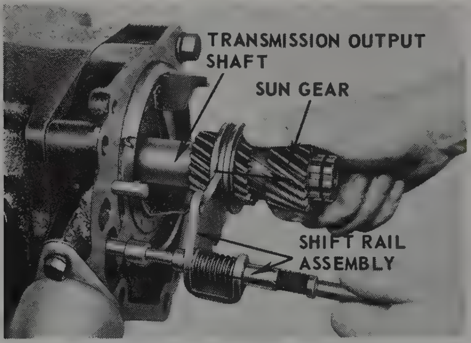

TRANSMISSION OUTPUT SHAFT
SUN GEAR
SHIFT RAIL ASSEMBLY

Fig. 27-68. Pulling sun gear and shift rail assembly as a unit. (Chevrolet)

as a unit. Pull the shift rail free of the transmission, Fig. 27-68.

Remove the solenoid fasteners. Turn the solenoid a quarter turn clockwise. This will release the solenoid plunger from the locking pawl. Pull the solenoid free, Fig. 27-69.

Pull the cover plate snap ring free, Fig. 27-70.

Remove the cover plate. This will permit withdrawl of the sun gear hub (balk ring gear) and pawl. Look at Figs. 27-70 and 27-71.

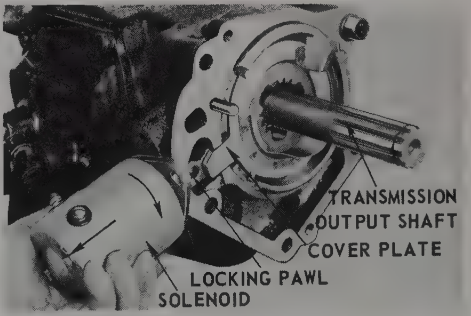

TRANSMISSION OUTPUT SHAFT
COVER PLATE
LOCKING PAWL
SOLENOID

Fig. 27-69. Removing solenoid.

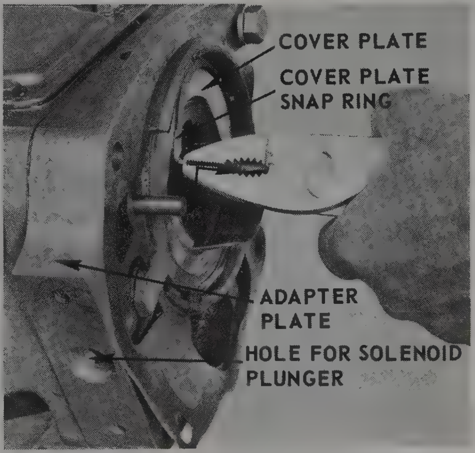

COVER PLATE
COVER PLATE SNAP RING
ADAPTER PLATE
HOLE FOR SOLENOID PLUNGER

Fig. 27-70. Removing cover plate snap ring. (American Motors)

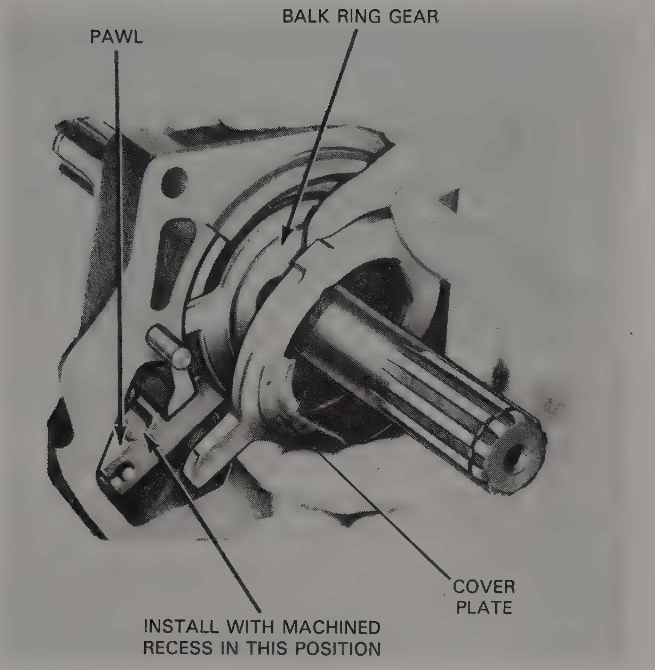


Fig. 27-71. Removing cover plate. Pawl and balk ring gear may now be removed. (Ford)

CLEAN AND INSPECT ALL PARTS

Clean all parts. Inspect all gear teeth for evidence of wear or chipping. Spin the planet gears on their shafts. They should turn easily but without excessive rock or play.

Check the clutch rollers. These must be accurate and free of chipping or galling. The clutch cam roller surfaces must not show grooving from the rollers. The inside of the clutch housing must be smooth.

Hold the roller cam hub and twist the roller retainer ring counterclockwise. When released, it must snap back QUICKLY. If it does not, replace the springs, Fig. 27-72.

Press on one end of the balk ring (in a direction that would tend to close ring). The ring should tighten and refuse to turn, Fig. 27-73.

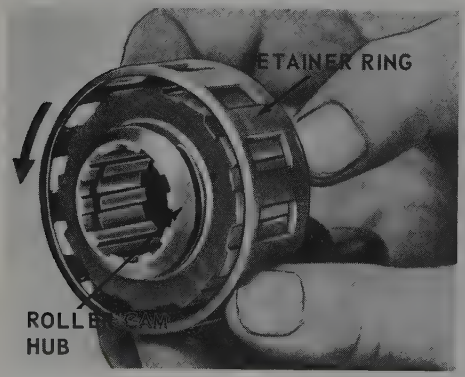


Fig. 27-72. Rotate roller retainer clockwise while holding hub. When released, the retainer should snap back quickly. (American Motors)

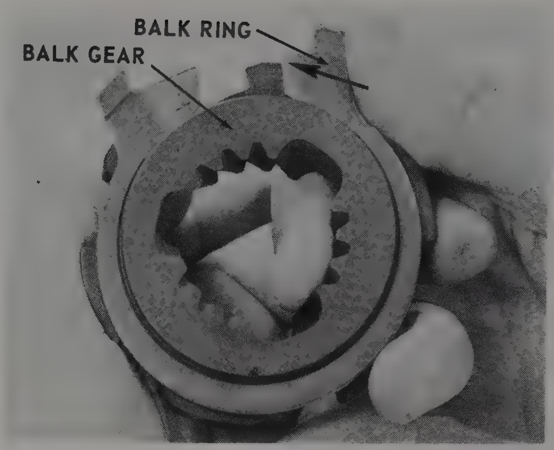


Fig. 27-73. Pressure on balk ring in this direction should lock ring to balk gear (sun gear hub).

While holding the balk ring gear in a vise, hook a spring scale to the balk ring in a manner that will attempt to open the ring. Pull on the scale until the ring starts turning. Read the pull required to KEEP IT MOVING. Check against specifications, Fig. 27-74.

Replace overdrive housing oil seal. Check bearings. Check case for cracks. Replace worn parts, lubricate, and reassemble in the reverse order of disassembly.

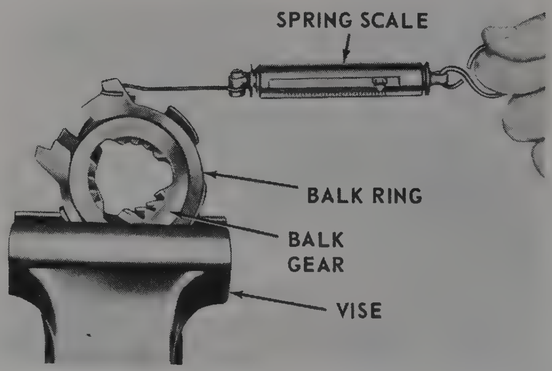


Fig. 27-74. Testing balk ring-to-balk gear tension.

OVERDRIVE – CONSTANT DRIVE TYPE

The hydraulically operated, constant drive overdrive unit bolts to the rear of the transmission much as the freewheeling type just discussed.

A cutaway view of one type of constant drive overdrive is pictured in Fig. 27-75. Study the part relationship.

An exploded view of a similar type of constant drive unit is illustrated in Fig. 27-76. The inner cone friction surface of sliding clutch (22) is forced against the tapered outer edge of the annulus gear when the unit

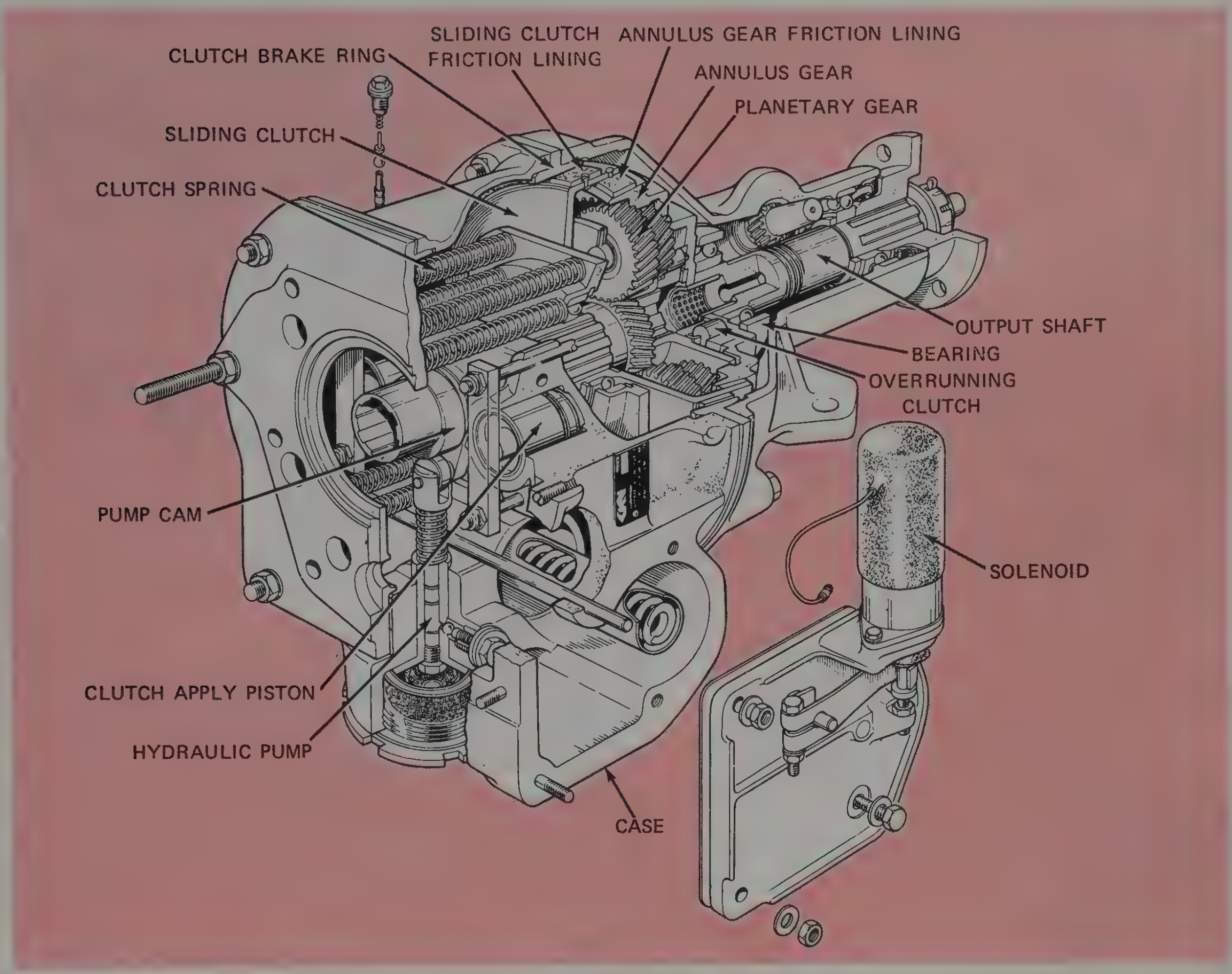

SLIDING CLUTCH FRICTION LINING
ANNULUS GEAR FRICTION LINING
CLUTCH BRAKE RING
ANNULUS GEAR
PLANETARY GEAR
SLIDING CLUTCH
CLUTCH SPRING
OUTPUT SHAFT
BEARING
OVERRUNNING CLUTCH
PUMP CAM
SOLENOID
CLUTCH APPLY PISTON
HYDRAULIC PUMP
CASE

Fig. 27-75. Cutaway of one type of hydraulically operated constant drive overdrive unit. Study parts and their relationship. (British-Leyland)

is in direct drive (1 to 1 ratio). Sliding clutch outer friction surface is forced against clutch brake ring (15) surface when in overdrive (0.75 to 1 ratio).

OVERDRIVE ACTION — DISENGAGED

Hydraulic pressure, sliding clutch, and planetary gearset action is shown for the disengaged position in Fig. 27-77. Study power flow.

OVERDRIVE ACTION — ENGAGED

At speeds above an average of 35 mph (56 Km/h), the governor speed switch makes it possible for the driver to energize the solenoid valve. This, in turn, applies hydraulic pressure to the clutch apply pistons. The pistons move the clutch, against spring pressure, until the planetary gearset is put into operation to produce the overdrive ratio (around 0.75 to 1.00 average). Power flow in the overdrive ENGAGED position is pictured in Fig. 27-78.

Note Figs. 27-77 and 27-78. Unlike the freewheeling overdrive, the constant drive unit has no period when drive is not transmitted both to and from the driveshaft. It is either in DIRECT or OVERDRIVE.

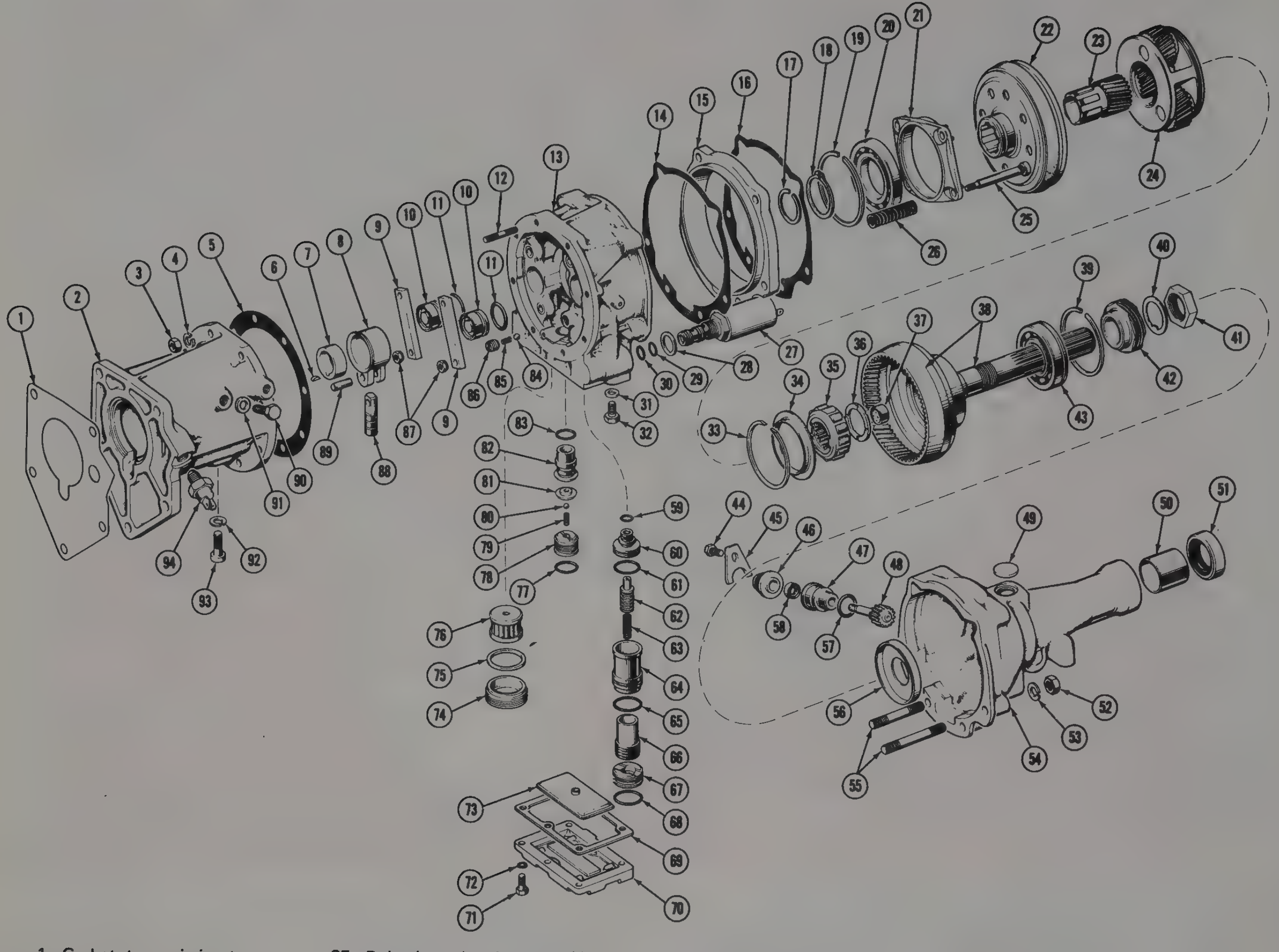
This unit may be operated without the use of the clutch. It may be operated under full power. A kickdown switch is used to de-energize the solenoid (places unit in disengaged direct drive) for additional power for passing.

CHECKING OIL LEVEL

The constant drive unit usually shares a common oil supply with the transmission. Oil level plug may be on the transmission, Fig. 27-79. When oil flows out transmission plug, overdrive level is also correct. When checking oil level, unit should be at operating temperature and the overdrive engaged and disengaged a couple of times.

TESTING OVERDRIVE HYDRAULIC PRESSURE

When experiencing problems related to pressure, car may be placed on a suitable lift. A hydraulic pressure



1. Gasket, transmission-to-adapter.
2. Adapter, transmission.
3. Nut, self-locking, main case stud.
4. Washer, lock.
5. Gasket, main case-to-transmission adapter.
6. Key, pump strap cam drive.
7. Cam, pump strap.
8. Strap, pump.
9. Bar, clutch piston apply.
10. Piston, clutch apply.
11. Seal, clutch apply piston O-ring.
12. Stud, main case-to-transmission adapter.
13. Main case.
14. Gasket, clutch brake ring (front).
15. Brake ring, clutch.
16. Gasket, clutch brake ring (rear).
17. Ring, sun gear snap.
18. Ring lock, sliding clutch.
19. Ring, thrust bearing snap.
20. Bearing, thrust.
21. Cover, thrust bearing.
22. Clutch, sliding.
23. Sun gear.
24. Assembly, pinion carrier.
25. Bolt, thrust bearing cover (4).
26. Spring, clutch return (4).
27. Solenoid valve.
28. Washer, solenoid valve.
29. Seal, solenoid valve O-ring.
30. Seal, solenoid valve O-ring.
31. Gasket, pressure plug.
32. Plug, main case pressure.
33. Ring, overrunning clutch snap.
34. Slinger, overrunning clutch oil.
35. Assembly, overrunning clutch.
36. Washer, mainshaft thrust.
37. Bushing, mainshaft support.
38. Mainshaft and annulus gear.
39. Ring, mainshaft bearing snap.
40. Washer, speedometer drive gear tab.
41. Nut, speedometer drive gear lock.
42. Gear, speedometer drive.
43. Bearing, mainshaft.
44. Bolt, speedometer adapter clamp.
45. Clamp, speedometer adapter.
46. Adapter, speedometer-to-governor speed switch.
47. Adapter, speedometer driven gear.
48. Gear, speedometer driven.
49. Plug, expansion.
50. Bushing, rear case.
51. Seal, rear case oil.
52. Nut, self-locking, main case-to-rear case stud.
53. Washer, lock.
54. Rear case.
55. Stud, main case-to-rear case.
56. Washer, disc.
57. Seal, speedometer adapter O-ring.
58. Seal, speedometer adapter oil.
59. Seal, relief valve body O-ring (inner).
60. Body, relief valve.
61. Seal, relief valve body O-ring (outer).
62. Assembly, relief valve and spring.
63. Spring, relief valve residual pressure.
64. Sleeve, relief valve.
65. Seal, relief valve sleeve O-ring.
66. Piston, relief valve.
67. Plug, relief valve piston.
68. Seal, relief valve piston plug O-ring.
69. Gasket, oil pan.
70. Oil pan.
71. Bolt, oil pan.
72. Washer, lock.
73. Filter, oil pan.
74. Plug, pressure filter.
75. Washer, pressure filter (aluminum)
76. Filter pressure.
77. Seal, pump body O-ring.
78. Plug, pump body.
79. Spring, nonreturn valve ball-seat.
80. Ball, nonreturn valve check.
81. Seat, nonreturn valve.
82. Body, pump plunger.
83. Seal, pump plunger body O-ring.
84. Ball, lubrication relief valve check.
85. Spring, lubrication relief valve.
86. Plug, lubrication relief valve.
87. Nut, self-locking, clutch piston apply bar.
88. Plunger, pump.
89. Pin, pump plunger.
90. Bolt, gearshift lever retainer-to adapter.
91. Washer, lock.
92. Washer, lock.
93. Bolt, rear support cushion-to-adapter.
94. Switch, back-up light.

Fig. 27-76. Exploded view of a slightly different design of constant drive overdrive. How many parts can you identify in Fig. 27-75 that are similar?

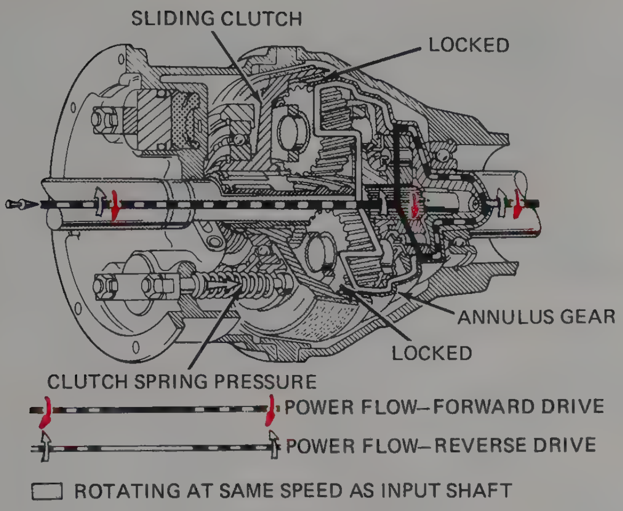

SLIDING CLUTCH
LOCKED
ANNULUS GEAR
LOCKED
CLUTCH SPRING PRESSURE
POWER FLOW–FORWARD DRIVE
POWER FLOW–REVERSE DRIVE
ROTATING AT SAME SPEED AS INPUT SHAFT

Fig. 27-77. Power flow through overdrive unit in DISENGAGED position. Note that sliding clutch is locked to annulus gear by clutch spring pressure. (American Motors)

gauge, Fig. 27-80, is attached to the main case pressure outlet (normally has a plug in outlet). Car is driven at recommended speeds. Then the pressure is noted in both engaged and disengaged modes. For a unit such as the one shown in Fig. 27-75, pressure when engaged should be around 530 psi (3 654 kPa). When disengaged, pressure should drop to around 20-40 psi (138-276 kPa). USE PROPER CAUTIONS WHEN OPERATING A CAR ON THE LIFT!

OVERHAUL

When working on a constant drive overdrive unit, follow manufacturer's directions and "specs." Clean all parts. CAUTION: DO NOT WASH SLIDING CLUTCH IN ANY SOLVENT. THIS WOULD RUIN FRICTION LINING BOND. Blow dry. Inspect for breakage, wear, burrs, and cracks. Blow parts clean. Upon assembly, coat with CLEAN transmission fluid. CLEANLINESS IS VITAL. Only a tiny amount of dirt can seriously impair the operation of the unit.

Where sealer is required, use sparingly. Prior to installation, pour about one pint of transmission lube into the unit via access hole in the front of the main case. Lube and road test upon completion of installation.

OVERDRIVE PROBLEMS

See problem diagnosis section at the end of this chapter.

FIVE SPEED TRANSMISSION OVERDRIVE GEAR

Many transmissions (both four and five speeds) make the upper gear (fourth and fifth) an overdrive gear. Study the transmissions in Figs. 27-1 and 27-79.

Five speed transmissions are also used in transaxles. These setups are in common use on front-wheel drive cars. See Figs. 27-81, 27-82, and 27-90.

These transmissions are diagnosed, serviced, and repaired much as the standard box in which the upper or high gear is direct (1 to 1). Refer to the manual transmission section of this chapter for service and repair. Refer to the diagnosis section for problem solving.

FOUR-WHEEL DRIVE

Four-wheel drive vehicles may use either a manual or an automatic transmission. They all use a TRANSFER CASE between the transmission output end and the system propeller shafts.

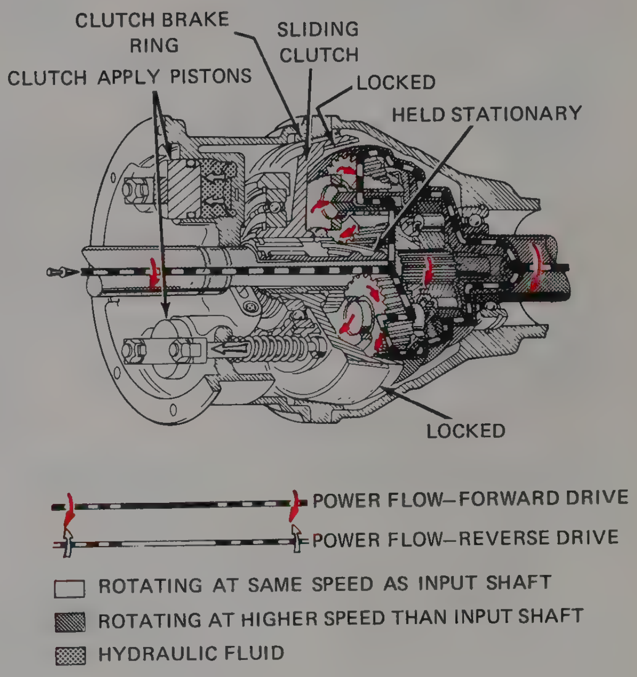

CLUTCH BRAKE RING
SLIDING CLUTCH
CLUTCH APPLY PISTONS
LOCKED
HELD STATIONARY
LOCKED
POWER FLOW–FORWARD DRIVE
POWER FLOW–REVERSE DRIVE
ROTATING AT SAME SPEED AS INPUT SHAFT
ROTATING AT HIGHER SPEED THAN INPUT SHAFT
HYDRAULIC FLUID

Fig. 27-78. Power flow through overdrive unit in ENGAGED position. Note that clutch apply pistons have drawn sliding clutch away from annulus gear surface, forcing it into engagement with clutch brake ring surface.

TRANSFER CASE

The transfer case is needed to apply transmission output shaft torque to both front and rear propeller shafts. Engine torque from the transmission output shaft is fed into the transfer case. Through a set of gears, chain and gears, or viscous coupling, power is transmitted to each propeller shaft. Fig. 27-83 illustrates a four-wheel drive setup with a transfer case. Note how both propeller shafts are attached to the transfer case.

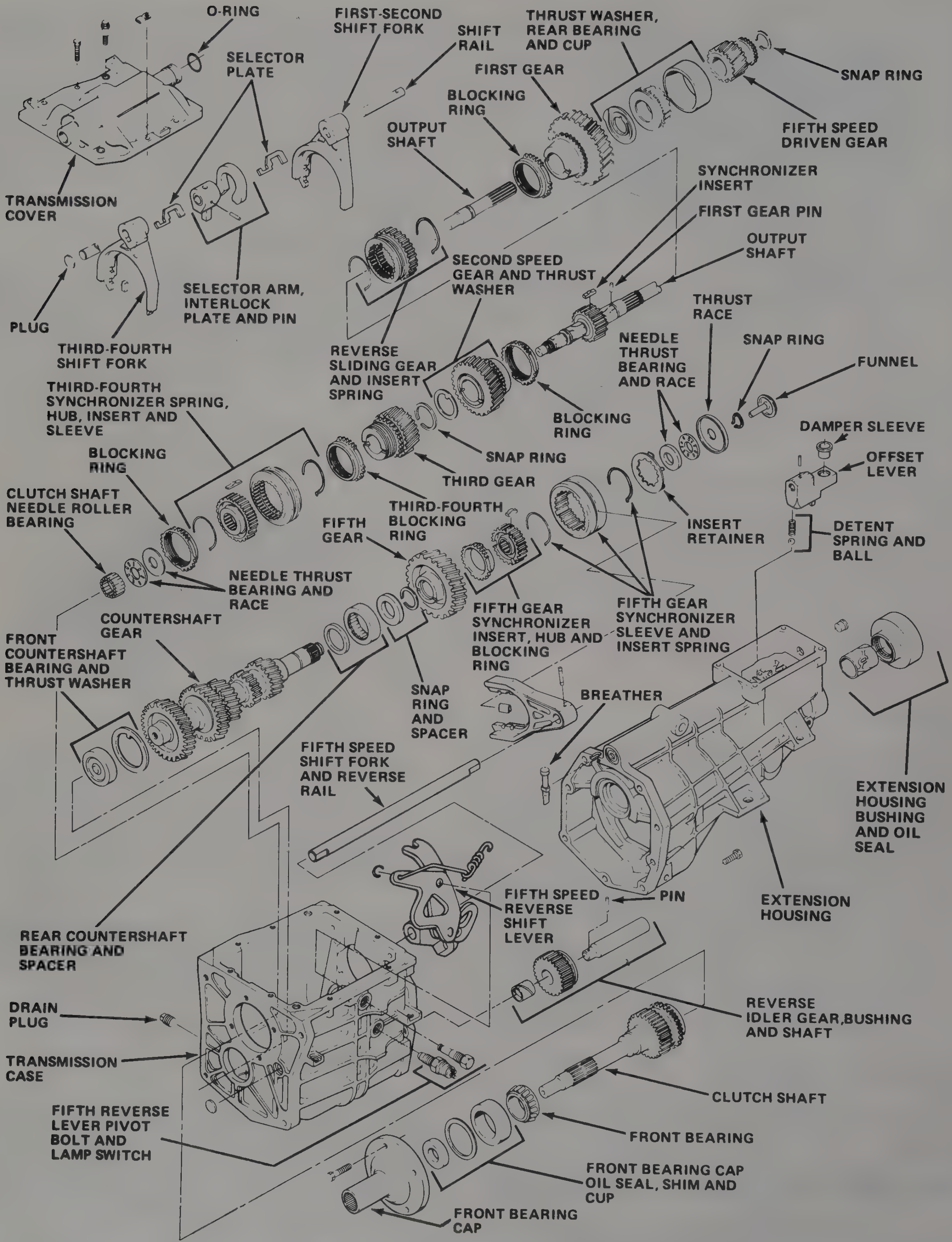

O-RING
FIRST-SECOND SHIFT FORK
SHIFT RAIL
THRUST WASHER, REAR BEARING AND CUP
SELECTOR PLATE
FIRST GEAR
SNAP RING
BLOCKING RING
OUTPUT SHAFT
FIFTH SPEED DRIVEN GEAR
TRANSMISSION COVER
SYNCHRONIZER INSERT
FIRST GEAR PIN
OUTPUT SHAFT
SECOND SPEED GEAR AND THRUST WASHER
SELECTOR ARM, INTERLOCK PLATE AND PIN
PLUG
THRUST RACE
THIRD-FOURTH SHIFT FORK
NEEDLE THRUST BEARING AND RACE
SNAP RING
FUNNEL
REVERSE SLIDING GEAR AND INSERT SPRING
THIRD-FOURTH SYNCHRONIZER SPRING, HUB, INSERT AND SLEEVE
BLOCKING RING
DAMPER SLEEVE
SNAP RING
OFFSET LEVER
BLOCKING RING
THIRD GEAR
CLUTCH SHAFT NEEDLE ROLLER BEARING
THIRD-FOURTH BLOCKING RING
INSERT RETAINER
FIFTH GEAR
DETENT SPRING AND BALL
NEEDLE THRUST BEARING AND RACE
FIFTH GEAR SYNCHRONIZER INSERT, HUB AND BLOCKING RING
FIFTH GEAR SYNCHRONIZER SLEEVE AND INSERT SPRING
COUNTERSHAFT GEAR
FRONT COUNTERSHAFT BEARING AND THRUST WASHER
SNAP RING AND SPACER
BREATHER
FIFTH SPEED SHIFT FORK AND REVERSE RAIL
EXTENSION HOUSING BUSHING AND OIL SEAL
FIFTH SPEED REVERSE SHIFT LEVER
PIN
EXTENSION HOUSING
REAR COUNTERSHAFT BEARING AND SPACER
DRAIN PLUG
REVERSE IDLER GEAR,BUSHING AND SHAFT
TRANSMISSION CASE
CLUTCH SHAFT
FIFTH REVERSE LEVER PIVOT BOLT AND LAMP SWITCH
FRONT BEARING
FRONT BEARING CAP OIL SEAL, SHIM AND CUP
FRONT BEARING CAP

Fig. 27-79. Exploded view of a five speed transmission. This unit uses an aluminum case, extension housing, and cover. Note fifth speed parts and relationship to each other. (AMC)

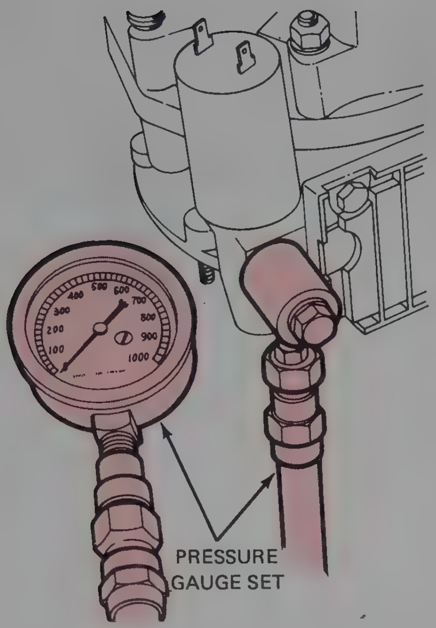

PRESSURE
GAUGE SET

Fig. 27-80. Using a pressure gauge to test overdrive hydraulic pressure during engaged and disengaged positions. (American Motors)

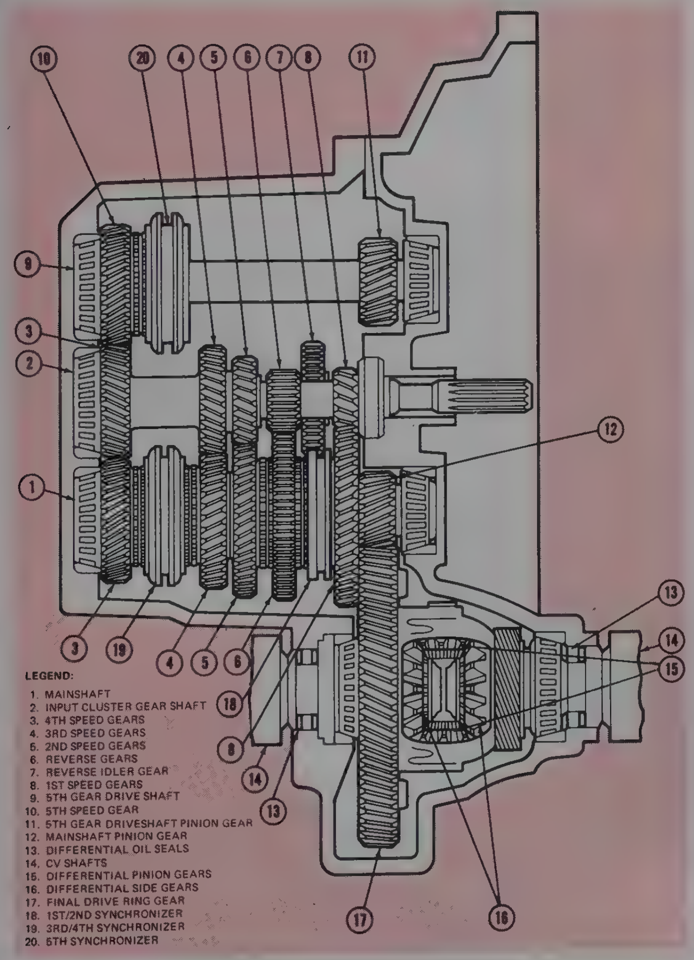

LEGEND:
1. MAINSHAFT
2. INPUT CLUSTER GEAR SHAFT
3. 4TH SPEED GEARS
4. 3RD SPEED GEARS
5. 2ND SPEED GEARS
6. REVERSE GEARS
7. REVERSE IDLER GEAR
8. 1ST SPEED GEARS
9. 5TH GEAR DRIVE SHAFT
10. 5TH SPEED GEAR
11. 5TH GEAR DRIVESHAFT PINION GEAR
12. MAINSHAFT PINION GEAR
13. DIFFERENTIAL OIL SEALS
14. CV SHAFTS
15. DIFFERENTIAL PINION GEARS
16. DIFFERENTIAL SIDE GEARS
17. FINAL DRIVE RING GEAR
18. 1ST/2ND SYNCHRONIZER
19. 3RD/4TH SYNCHRONIZER
20. 5TH SYNCHRONIZER

Fig. 27-81. Cross-sectional view of a five speed manual transaxle unit as used in one front-wheel drive car. Study parts, locations, and relationships. (Ford)

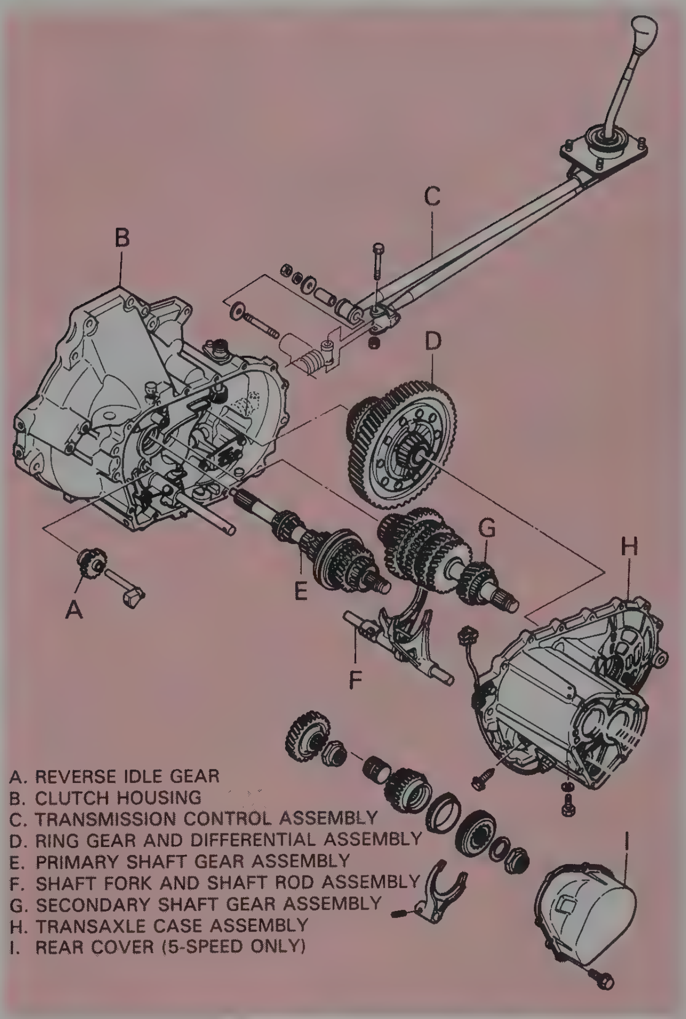

A. REVERSE IDLE GEAR
B. CLUTCH HOUSING
C. TRANSMISSION CONTROL ASSEMBLY
D. RING GEAR AND DIFFERENTIAL ASSEMBLY
E. PRIMARY SHAFT GEAR ASSEMBLY
F. SHAFT FORK AND SHAFT ROD ASSEMBLY
G. SECONDARY SHAFT GEAR ASSEMBLY
H. TRANSAXLE CASE ASSEMBLY
I. REAR COVER (5-SPEED ONLY)

Fig. 27-82. Exploded view of one type of manual transaxle. (Mazda)

TRANSFER CASE ACTION — LOW RANGE, HIGH RANGE

Study Fig. 27-84 and follow power flow. Start with the transmission output shaft.

The output shaft is splined to, and drives, the transfer case MAIN DRIVE gear. The main drive gear is in constant mesh with the IDLER CLUSTER GEAR. The idler turns freely in needle bearings on the idler shaft. Note that the idler cluster is made up of TWO gears, one large (high range) and one small (low range). These gears are in constant mesh with the OUTPUT GEARS. Both output gears turn freely in bushings on the transfer case OUTPUT SHAFT.

The SLIDING CLUTCH is splined to the output shaft. In the neutral position (shown), it is centered between, but not engaging the output gears. Low range (high engine rpm, low wheel rpm) is engaged when the sliding clutch is shifted into engagement with the low range output gear. High range (low engine speed rpm, high drive wheel rpm) is engaged when the sliding clutch

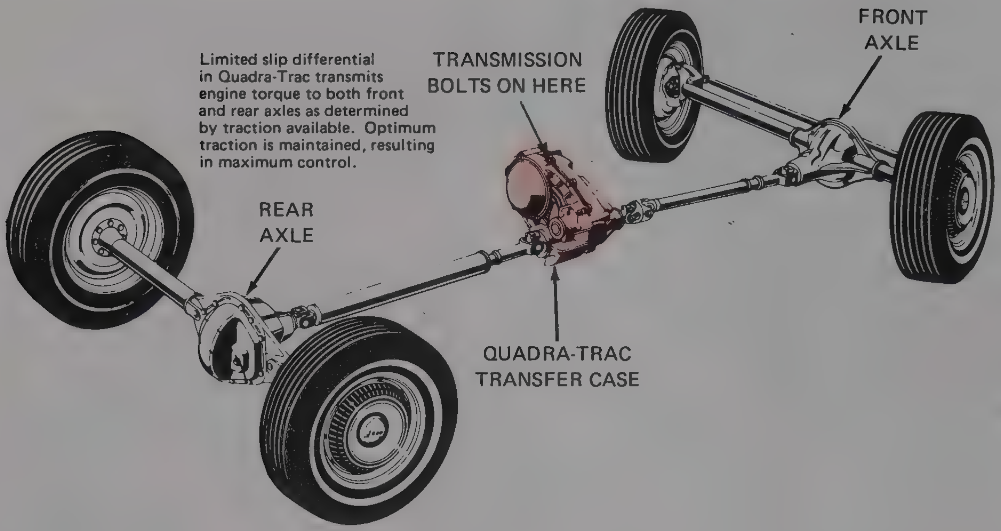

Limited slip differential in Quadra-Trac transmits engine torque to both front and rear axles as determined by traction available. Optimum traction is maintained, resulting in maximum control.
TRANSMISSION BOLTS ON HERE
FRONT AXLE
REAR AXLE
QUADRA-TRAC TRANSFER CASE

Fig. 27-83. Typical four-wheel drive setup. Note how transfer case drives both front and rear propeller shafts. (Jeep)

is moved into engagement with the high range output gear. The output gear that is engaged with the clutch turns the sliding clutch and, since the clutch is splined to the output shaft, the shaft also turns.

TWO-WHEEL, FOUR-WHEEL DRIVE ACTION

The transfer case output shaft is made of two parts, Fig. 27-84. The long section is driven by the sliding splined clutch. This long section of the output shaft, in turn, will drive the rear propeller shaft. The shorter front section is connected to the long section ONLY when the four-wheel drive sliding splined clutch (splined to and constantly turned by long section) is moved into engagement with the splined end of the short shaft.

When two-wheel drive is desired, the short output shaft is disconnected by moving the four-wheel sliding

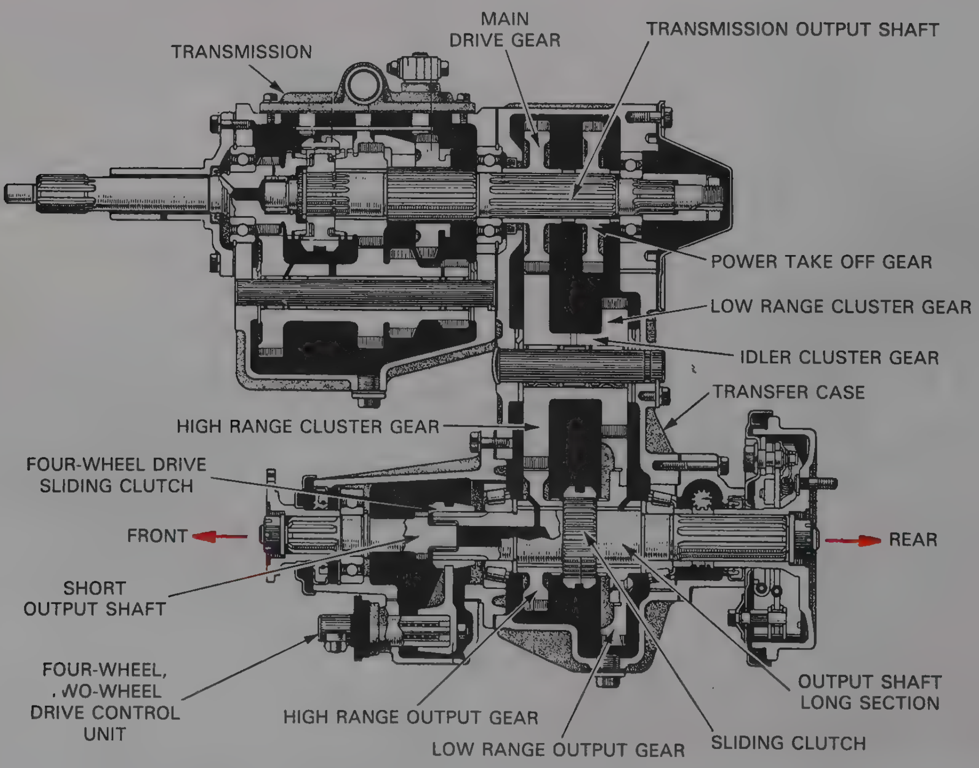

TRANSMISSION
MAIN DRIVE GEAR
TRANSMISSION OUTPUT SHAFT
POWER TAKE OFF GEAR
LOW RANGE CLUSTER GEAR
IDLER CLUSTER GEAR
TRANSFER CASE
HIGH RANGE CLUSTER GEAR
FOUR-WHEEL DRIVE SLIDING CLUTCH
FRONT
REAR
SHORT OUTPUT SHAFT
FOUR-WHEEL, TWO-WHEEL DRIVE CONTROL UNIT
HIGH RANGE OUTPUT GEAR
LOW RANGE OUTPUT GEAR
SLIDING CLUTCH
OUTPUT SHAFT LONG SECTION

Fig. 27-84. One type of transfer case as used on a part-time four-wheel drive system. (Toyota)

clutch out of engagement. The long shaft will then drive the rear propeller shaft, but will not apply torque to the front.

Four-wheel drive mode is accomplished by merely moving the four-wheel clutch into engagement with the short shaft. Torque will then be applied to both front and rear propeller shafts.

Vehicles equipped with this type of transfer case must NEVER BE OPERATED IN FOUR-WHEEL DRIVE ON DRY, HARD-SURFACED ROADS! The vehicle's front wheels rotate slightly faster (they follow a more curved path) than the rear. As a result, internal stresses (windup) build up in the entire drive train until something "breaks." This WILL occur, unless the tires "slip" (not easily done on hard, dry road surfaces) to relieve the strain.

FULL-TIME FOUR-WHEEL DRIVE

Another type of transfer case, utilizing a drive chain, sprockets, gears, and a DIFFERENTIAL unit, permits the vehicle to constantly operate in four-wheel drive — on any and all road surfaces. One such unit is the "Quadra-Trac," Fig. 27-85. Note that the drive chain transmits power from the drive sprocket to the differential case sprocket. A differential unit inside the case applies driving torque to both front and rear transfer case output shafts. The differential allows front and back shafts to rotate at different speeds while still applying power. This prevents harmful "windup" and permits constant use in four-wheel drive.

This unit employs a limited-slip type of differential that will still provide some drive to either the front or rear axle if one wheel is spinning. For very severe traction situations, the unit has a mechanism to lockout (stop) the differential action. This provides drive to both front and rear propeller shafts. NEVER USE LOCKOUT CONTROL ON DRY, HARD ROADS. USE ONLY WHEN STUCK OR UNDER VERY POOR TRACTION SITUATIONS.

Fig. 27-85 shows a cutaway of the full-time drive "Quadra-Trac" transfer case. Note the planetary gear LOW RANGE reduction unit.

An exploded view of the "Quadra-Trac" is illustrated in Fig. 27-86. Note use of the limited slip differential unit. This transfer case is available with or without a low range reduction unit. Fig. 27-86 does not show the reduction unit.

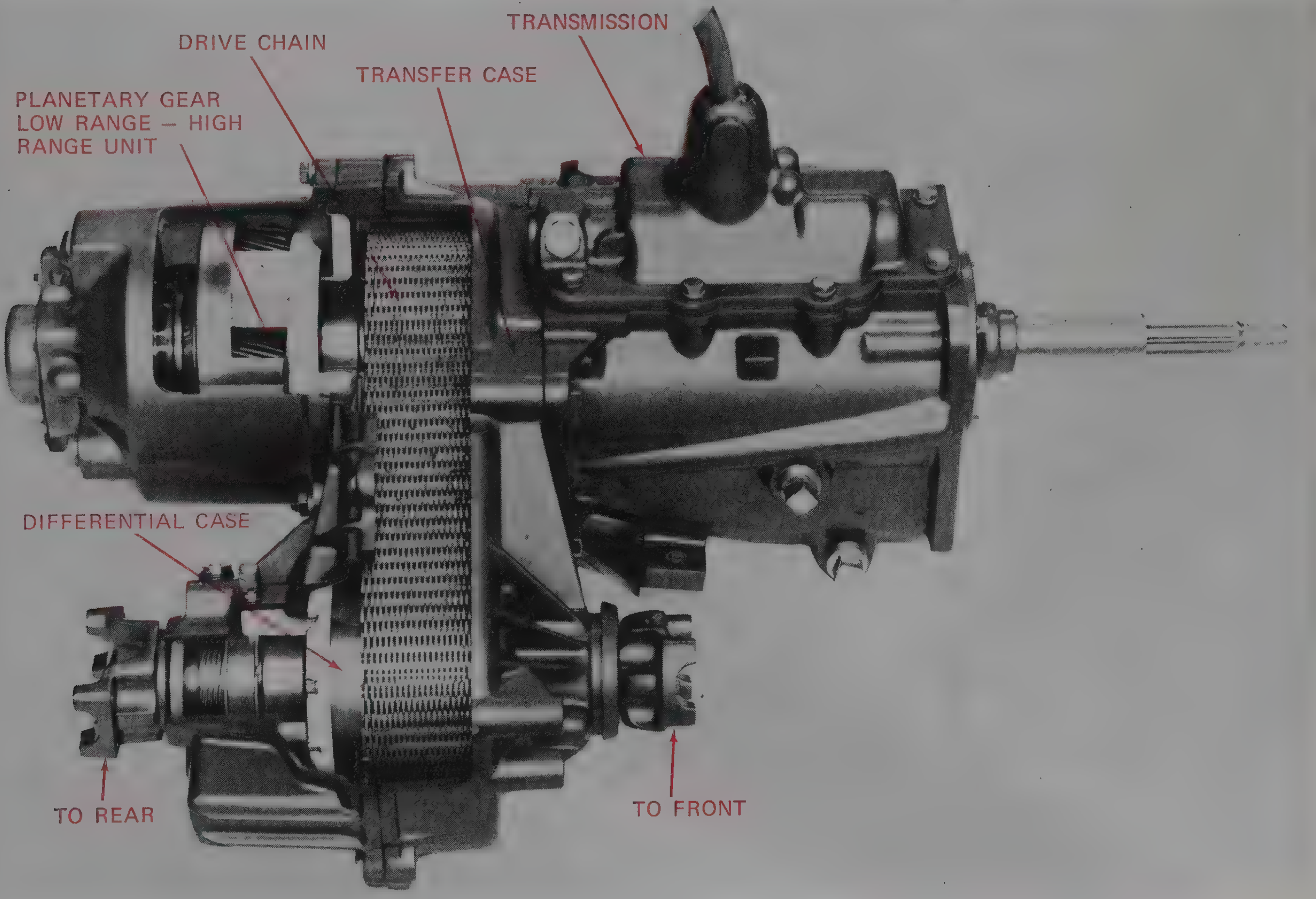


Fig. 27-85. Cutaway of Jeep "Quadra-Trac" transfer case. Note use of chain to drive differential unit.

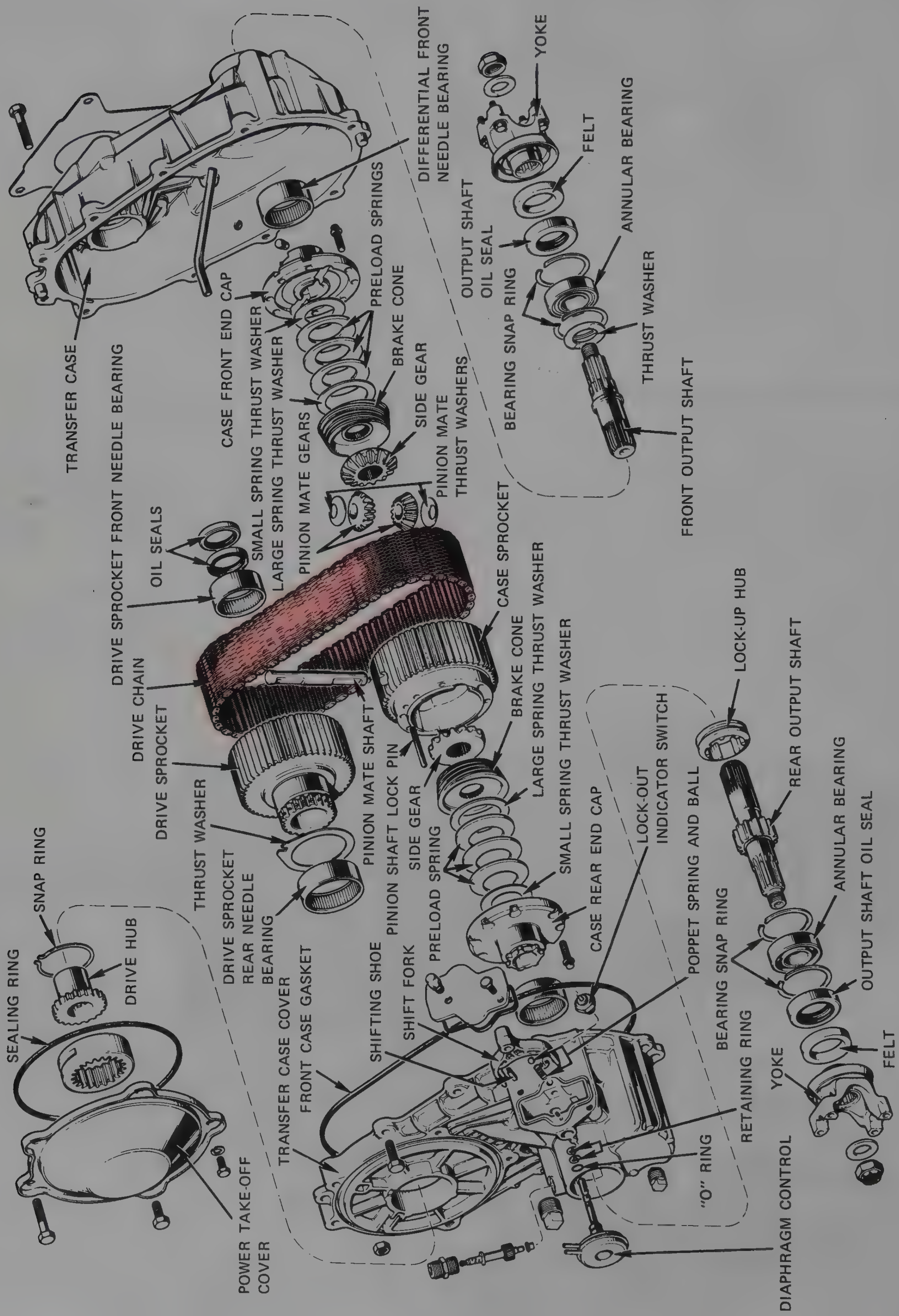

TRANSFER CASE
DIFFERENTIAL FRONT NEEDLE BEARING
CASE FRONT END CAP
SMALL SPRING THRUST WASHER
LARGE SPRING THRUST WASHER
PRELOAD SPRINGS
BRAKE CONE
SIDE GEAR
PINION MATE THRUST WASHERS
PINION MATE GEARS
YOKE
FELT
ANNULAR BEARING
OUTPUT SHAFT OIL SEAL
BEARING SNAP RING
THRUST WASHER
FRONT OUTPUT SHAFT
DRIVE SPROCKET FRONT NEEDLE BEARING
OIL SEALS
CASE SPROCKET
LARGE SPRING THRUST WASHER
SMALL SPRING THRUST WASHER
DRIVE CHAIN
DRIVE SPROCKET
PINION MATE SHAFT
BRAKE CONE
PINION SHAFT LOCK PIN
SIDE GEAR
PRELOAD SPRING
THRUST WASHER
DRIVE SPROCKET REAR NEEDLE BEARING
CASE REAR END CAP
LOCK-UP HUB
REAR OUTPUT SHAFT
LOCK-OUT INDICATOR SWITCH
POPPET SPRING AND BALL
ANNULAR BEARING
OUTPUT SHAFT OIL SEAL
BEARING SNAP RING
FELT
YOKE
RETAINING RING
"O" RING
DIAPHRAGM CONTROL
SNAP RING
SEALING RING
DRIVE HUB
SHIFTING SHOE
SHIFT FORK
TRANSFER CASE COVER
FRONT CASE GASKET
POWER TAKE-OFF COVER

Fig. 27-86. Exploded view of a Jeep ''Quadra-Trac'' transfer case. Available low range unit is not shown.

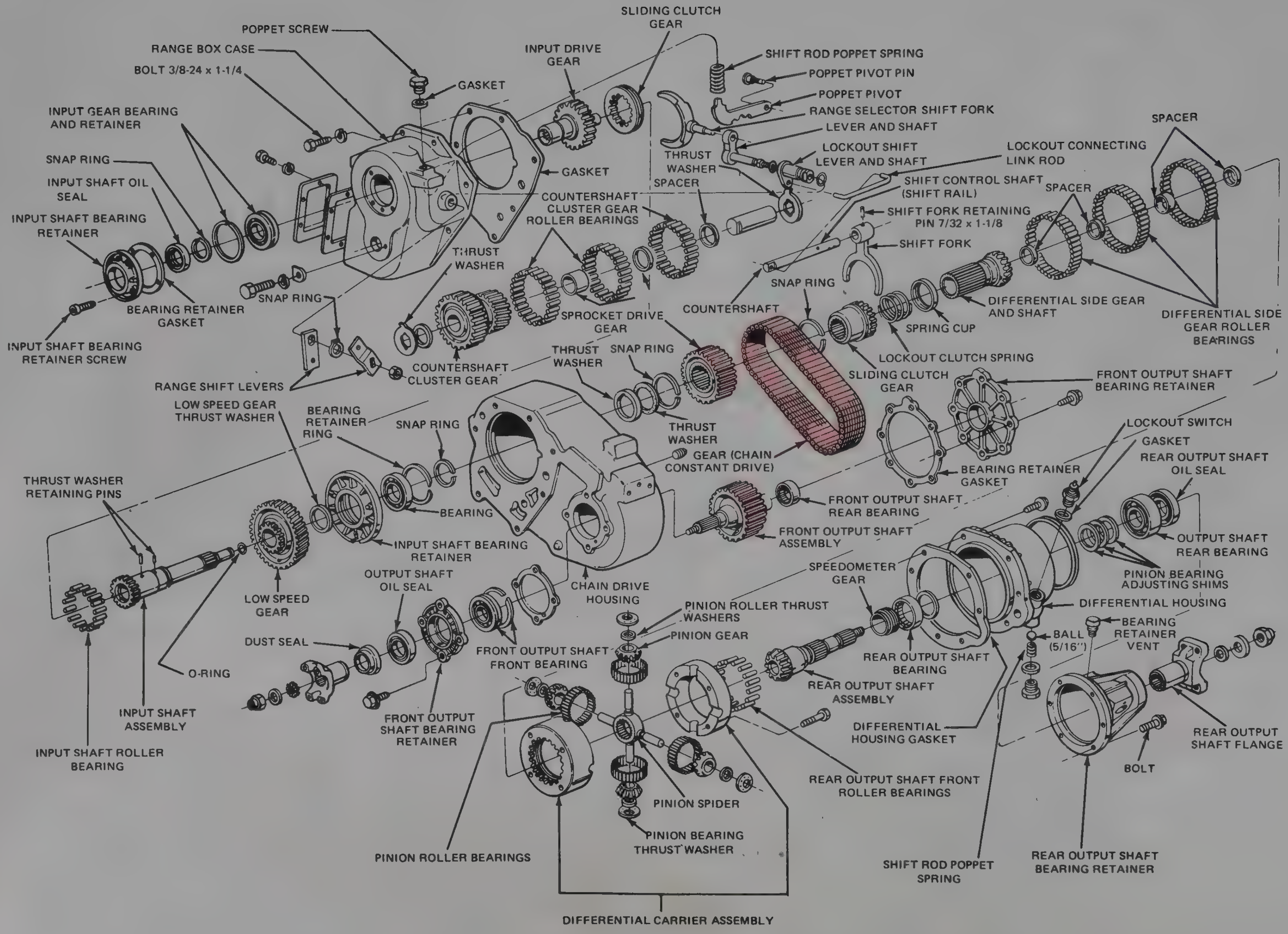
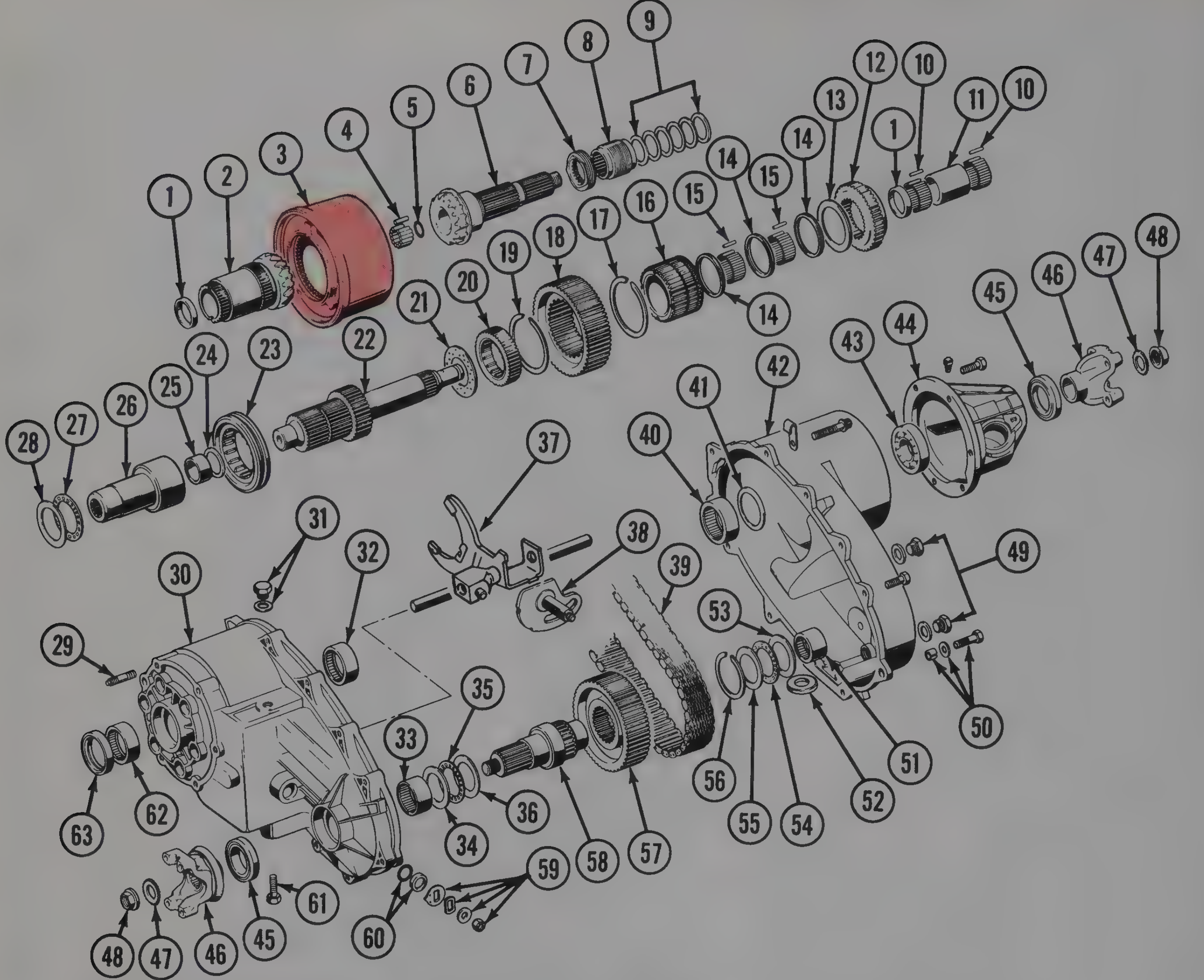

POPPET SCREW
RANGE BOX CASE
BOLT 3/8-24 x 1-1/4
GASKET
INPUT GEAR BEARING AND RETAINER
SNAP RING
INPUT SHAFT OIL SEAL
INPUT SHAFT BEARING RETAINER
BEARING RETAINER GASKET
INPUT SHAFT BEARING RETAINER SCREW
SNAP RING
RANGE SHIFT LEVERS
INPUT DRIVE GEAR
GASKET
SLIDING CLUTCH GEAR
THRUST WASHER
SPACER
COUNTERSHAFT CLUSTER GEAR ROLLER BEARINGS
THRUST WASHER
COUNTERSHAFT CLUSTER GEAR
SPROCKET DRIVE GEAR
SHIFT ROD POPPET SPRING
POPPET PIVOT PIN
POPPET PIVOT
RANGE SELECTOR SHIFT FORK
LEVER AND SHAFT
LOCKOUT SHIFT LEVER AND SHAFT
LOCKOUT CONNECTING LINK ROD
SHIFT CONTROL SHAFT (SHIFT RAIL)
SHIFT FORK RETAINING PIN 7/32 x 1-1/8
SHIFT FORK
COUNTERSHAFT
SNAP RING
SPACER
SPACER
DIFFERENTIAL SIDE GEAR AND SHAFT
SPRING CUP
LOCKOUT CLUTCH SPRING
SLIDING CLUTCH GEAR
DIFFERENTIAL SIDE GEAR ROLLER BEARINGS
THRUST WASHER
SNAP RING
THRUST WASHER
GEAR (CHAIN CONSTANT DRIVE)
FRONT OUTPUT SHAFT BEARING RETAINER
BEARING RETAINER GASKET
LOCKOUT SWITCH
GASKET
REAR OUTPUT SHAFT OIL SEAL
LOW SPEED GEAR THRUST WASHER
BEARING RETAINER RING
SNAP RING
THRUST WASHER RETAINING PINS
BEARING
INPUT SHAFT BEARING RETAINER
LOW SPEED GEAR
OUTPUT SHAFT OIL SEAL
CHAIN DRIVE HOUSING
FRONT OUTPUT SHAFT REAR BEARING
FRONT OUTPUT SHAFT ASSEMBLY
SPEEDOMETER GEAR
OUTPUT SHAFT REAR BEARING
PINION BEARING ADJUSTING SHIMS
DIFFERENTIAL HOUSING
BEARING RETAINER VENT
BALL (5/16")
DUST SEAL
O-RING
INPUT SHAFT ASSEMBLY
INPUT SHAFT ROLLER BEARING
FRONT OUTPUT SHAFT FRONT BEARING
FRONT OUTPUT SHAFT BEARING RETAINER
PINION ROLLER THRUST WASHERS
PINION GEAR
REAR OUTPUT SHAFT BEARING
REAR OUTPUT SHAFT ASSEMBLY
DIFFERENTIAL HOUSING GASKET
REAR OUTPUT SHAFT FLANGE
BOLT
PINION SPIDER
PINION BEARING THRUST WASHER
REAR OUTPUT SHAFT FRONT ROLLER BEARINGS
PINION ROLLER BEARINGS
SHIFT ROD POPPET SPRING
REAR OUTPUT SHAFT BEARING RETAINER
DIFFERENTIAL CARRIER ASSEMBLY

Fig. 27-87. New Process 203 transfer case. This case uses a chain to drive the differential unit. It does not employ limited slip feature in differential. It does not use planetary gears to achieve low range. Conventional type gearing is used. (Ford)



1. MAINSHAFT BEARING SPACERS (SHORT) (2)
2. SIDE GEAR
3. VISCOUS COUPLING
4. MAINSHAFT PILOT BEARINGS
5. MAINSHAFT O-RING
6. REAR OUTPUT SHAFT
7. OIL PUMP
8. SPEEDOMETER DRIVE GEAR
9. DIFFERENTIAL SHIMS
10. MAINSHAFT NEEDLE BEARINGS (82)
11. MAINSHAFT NEEDLE BEARING SPACER (LONG) (1)
12. CLUTCH GEAR
13. CLUTCH GEAR THRUST WASHER
14. SPROCKET CARRIER NEEDLE BEARING SPACER (3)
15. SPROCKET CARRIER NEEDLE BEARINGS (120)
16. SPROCKET CARRIER
17. SPROCKET CARRIER SNAP RING
18. DRIVE SPROCKET
19. SPROCKET CARRIER SANP RING
20. SPLINE GEAR
21. MAINSHAFT THRUST WASHER
22. MAINSHAFT
23. CLUTCH SLEEVE
24. MAINSHAFT THRUST WASHER
25. MAINSHAFT BUSHING
26. INPUT GEAR
27. INPUT GEAR THRUST BEARING
28. INPUT GEAR THRUST BEARING RACE
29. MOUNTING GEAR
30. FRONT CASE
31. PLUG AND WASHER
32. INPUT GEAR REAR BEARING
33. FRONT OUTPUT SHAFT FRONT BEARING
34. FRONT OUTPUT SHAFT FRONT THRUST BEARING RACE (THICK)
35. FRONT OUTPUT SHAFT FRONT THRUST BEARING
36. FRONT OUTPUT SHAFT FRONT THRUST BEARING RACE (THIN)
37. RANGE FORK AND RAIL
38. RANGE SECTOR
39. DRIVE CHAIN
40. REAR OUTPUT SHAFT BEARING
41. REAR OUTPUT SHAFT BEARING SEAL
42. REAR CASE
43. REAR OUTPUT BEARING
44. REAR RETAINER
45. YOKE SEAL
46. YOKE
47. SEAL WASHER
48. YOKE NUT
49. FILL AND DRAIN PLUGS
50. ALIGNMENT DOWEL, WASHER AND BOLT
51. FRONT OUTPUT SHAFT REAR BEARING
52. MAGNET
53. FRONT OUTPUT SHAFT REAR THRUST BEARING RACE (THICK)
54. FRONT OUTPUT SHAFT REAR THRUST BEARING
55. FRONT OUTPUT SHAFT REAR THRUST BEARING RACE (THIN)
56. DRIVEN SPROCKET RETAINING SNAP RING
57. DRIVEN SPROCKET
57. DRIVEN SPROCKET
58. FRONT OUTPUT SHAFT
59. RANGE SECTOR SHAFT RETAINING LOCKNUT AND WASHERS
60. RANGE SECTOR SHAFT SEAL AND RETAINER
61. POSITIVE LOCK DETENT BOLT
62. INPUT GEAR FRONT BEARING
63. INPUT GEAR SEAL

Fig. 27-88. Exploded view of a "viscous coupling" transfer case assembly. This case can be shifted manually or with vacuum motors. (AMC)

Another type of full-time transfer case is pictured in Fig. 27-87. It uses a chain drive and a standard (non-limited slip) differential unit. Low and high range is accomplished through gearing. It may be locked out when wheel spin is experienced. DO NOT OPERATE IN LOCKOUT ON HARD DRY ROADS! Study the parts involved.

FULL-TIME, SELECT DRIVE TRANSFER CASE — OPERATION

This transfer case operates somewhat like the "Quadra-Trac" unit. The basic difference being the VISCOUS COUPLING used in place of the mechanical limited slip differential. See Fig. 27-88.

The viscous coupling contains a special silicone fluid that acts as a torque biasing (equalizing), limited slip unit. The coupling is attached to the front drive shaft by the side gear and drive sprocket. These turn the driven sprocket and front output shaft. The two sprockets are connected with a drive chain.

The rear drive shaft is attached to the viscous coupling through the rear output shaft side gear teeth. These teeth are meshed with the differential pinions.

During normal operation (no wheel spin), the viscous coupling does not operate. When excessive wheel spin is present (causing pronounced speed variations between front and rear axles), the coupling transfers torque to the axle having best traction, either front or rear.

The silicone fluid in the coupling is highly viscous (thick) and will not thin due to heat. As one axle overspeeds because of wheel slippage, the coupling rotational speed also increases. As the coupling speed becomes higher, the fixed clutch plates are forced to rotate in the silicone fluid as they too increase in speed. As fluid is forced between the clutch plates and displaced (moved), it expands creating friction and more resistance to higher input speed.

The coupling does not lock the axles together. It controls the amount of slipping. While at the same time, it sends maximum torque to the slower moving axle. Transfer case power flow is shown in Fig. 27-89.

CAUTION! The viscous coupling and pinion assembly are NOT serviceable as a unit. They are sealed together and the silicone fluid is not replaceable. If the

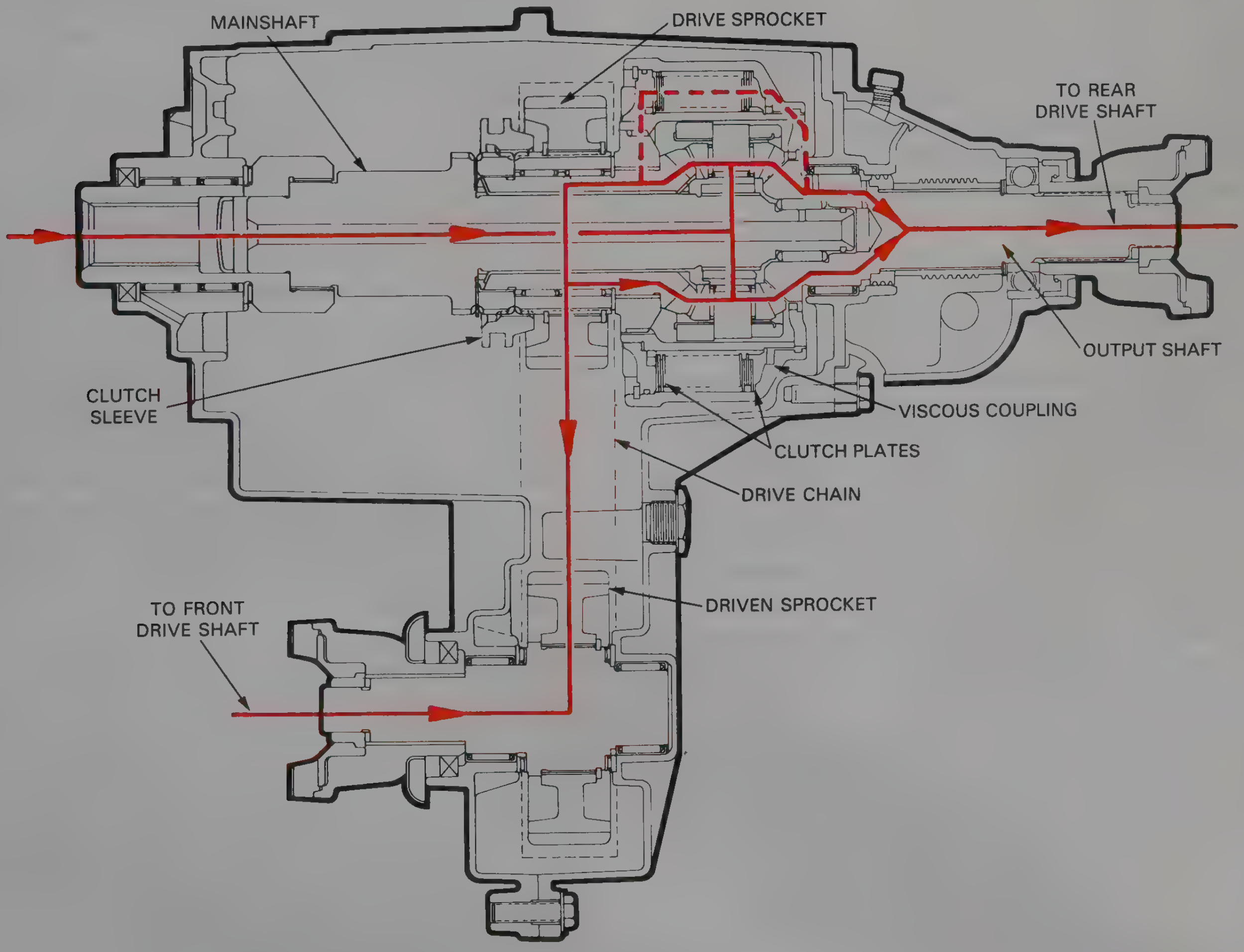


Fig. 27-89. Power flow schematic of a viscous coupling transfer case. Solid red line is constant power flow to front and rear axles. Dotted line represents power flow through coupling when wheel spinning (loss of traction) is encountered. (AMC)

coupling and/or pinions are damaged, replace entire unit with a new one.

TRANSFER CASE

Follow manufacturer's directions for transfer case lubricant type and viscosity. The "Quadra-Trac" requires a special lubricant for the limited slip unit. Check lubricant level. Do not overfill. Change as recommended.

Transfer case overhaul is similar to that of the transmission and differential. Use a manufacturer's manual and disassemble the unit as directed. Clean and examine all parts. Replace parts as needed. Assemble in reverse order. Lube parts prior to assembly. Torque fasteners. Install in vehicle. Check lube level and road test.

SUMMARY

Car transmissions are of three, four, and five speed design. Current practice is toward full synchronization for all forward speeds. An overdrive may be incorporated. Transaxle axle setups are used on front-wheel drive vehicles. The transmission and differential assembly are one unit.

Remove transmission only when necessary.

To remove a transmission, drain the oil. Remove all controls, wires, etc. Drop propeller shaft. Remove housing-to-transmission fasteners and pull transmission back. Use pilot bolts or jack. Do not allow the transmission to hang on the input shaft at any time.

Clean the outside of the transmission before disassembly.

Flush inside of transmission and examine gear teeth. Make any needed end play and clearance checks before disassembly.

General disassembly requires dropping the countergear to the bottom of the case (use a dummy shaft) and then removing either the input or output shaft first. A manufacturer's service manual should be available for reference.

Place the transmission on a stand. If hammering is required, use a soft face type. Keep all synchronizer parts together. Be careful to avoid losing any roller or needle bearings, snap rings, springs, or detent balls. Place them in a separate container. All parts must be thoroughly cleaned.

Inspect all synchronizer parts for excessive wear, chipping, galling, cracking, and proper operation. Check synchronizer clutch sleeve teeth, as well as the corresponding gear clutch teeth. Teeth should not be chipped, tapered, or excessively worn.

Synchronizer blocking rings should show some sign of fine tooling lines on the inside tapered surface.

When reassembling synchronizers, make certain the hub and clutch sleeve marks are aligned and that the inserts and springs are correctly installed.

Always install new seals. Use new gaskets and apply gasket cement. Some use RTV sealer or O-rings. When lock pins pass through the case, use sealer and stake the pins. Use new thrust washers and snap rings. Lubricate all parts as they are installed. Avoid using heavy force to make parts fit.

Compare new parts with used parts for size, shape, and operation. Where heavy damage was incurred. check the case, gears, and shaft for cracking.

Use soft grease to hold roller and needle bearings in place during assembly. Do not plug lubricant entry holes. Use grease that readily dissolves in oil.

Make certain snap rings are properly seated.

Use a dummy shaft to install the countergear in the case.

Make certain fasteners are of the proper length. Seal threads on fastener holes that pass through the transmission case.

When assembled, check for correct end play on all parts. All moving parts must turn freely and without catching. Check shifting action.

Align shifter forks carefully when installing shift cover. Install transmission. Fill with recommended lubricant (SLOWLY). Make all necessary connections.

Check shift linkage adjustment. Road test and recheck lubricant level.

Before condemning the overdrive unit, make a thorough check of the mechanical controls and the electrical system.

On some cars, it is possible to remove the overdrive unit while the transmission is in the car. General practice, however, calls for removing the transmission.

Unless the transmission requires work, do not allow the adapter plate to move away from the transmission when pulling the overdrive unit.

Following disassembly, clean and inspect all parts. Check gear teeth, roller clutch cam, cam action, and rollers. Test balk ring tension. Check case for cracks.

Lubricate parts as assembled. Use new seals and gaskets. Assemble in reverse order of disassembly.

On constant drive units, make certain all parts are CLEAN and lubed before assembly. Never wash sliding clutch in solvents.

Transfer cases are of two types, part-time and full-time. Never operate the part-time unit in four-wheel drive on dry, hard roads. Full-time units are always in four-wheel drive, but must not be operated in the "lockout" position on dry, hard road surfaces.

Use proper lubricant for the type of transfer case at hand. For overhaul, use manufacturer's manual and follow instructions. Checking, cleaning, etc., procedures are similar to that of transmissions (and differential for full-time units).

Use proper handling equipment as some transfer cases are HEAVY.

TRANSMISSION/TRANSAXLE PROBLEM DIAGNOSIS

PROBLEM: SHIFTS HARD — ALL GEARS

Possible Cause	Correction
1. Excessive clutch pedal free travel.	1. Adjust free travel.
2. Worn or defective clutch.	2. Replace worn parts.
3. Failure to fully depress clutch pedal when shifting.	3. Instruct driver.
4. Shift cover loose.	4. Tighten cover.
5. Shift fork, shafts, levers, or detents worn or loose.	5. Tighten or replace.
6. Improper shift linkage adjustment.	6. Adjust linkage.
7. Linkage needs lubrication.	7. Lubricate.
8. Linkage binding, bent, or loose.	8. Free, straighten, or tighten as needed.
9. Wrong transmission lubricant.	9. Drain and fill with recommended lubricant.
10. Insufficient lubricant.	10. Add lubricant to filler plug level.
11. Excess amount of lubricant.	11. Drain to level of filler plug.
12. Transmission misaligned.	12. Correct alignment.
13. Input shaft bearing retainer loose or cracked.	13. Tighten or replace retainer.
14. Synchronizer worn, damaged, or improperly assembled.	14. Replace or reassemble synchronizer.

PROBLEM: GEAR CLASH DURING DOWNSHIFTING

Possible Cause	Correction
1. Synchronizer worn, damaged, or improperly assembled.	1. Replace or reassemble synchronizer.
2. Shifting too fast (ramming into lower gear).	2. Force into gear with a smooth, slower shift.
3. Shifting to a lower gear when road speed is excessive.	3. Slow down to appropriate speed before shifting.
4. Clutch not releasing properly.	4. Adjust or repair as needed.
5. Excessive output shaft end play.	5. Adjust end play.
6. (See Hard Shifting — All Gears.)	

PROBLEM: JUMPS OUT OF GEAR

Possible Cause	Correction
1. Transmission loose or misaligned.	1. Tighten and/or align.
2. Clutch housing loose or misaligned.	2. Tighten and/or align.
3. Shift linkage improperly adjusted.	3. Adjust linkage.
4. Shift rail detents worn or detent springs weak.	4. Replace detents and/or springs.
5. Synchronizer clutch sleeve teeth worn.	5. Replace synchronizer.
6. Loose shifter cover.	6. Tighten cover.
7. Shift fork, shaft, or levers worn.	7. Replace worn part.
8. Worn clutch teeth on input shaft or other gears.	8. Replace input shaft or gears.
9. Worn gear teeth.	9. Replace gear.
10. Worn countergear bearings and/or thrust washers.	10. Replace countergear shaft, bearings, and washers.
11. Worn reverse idler gear bushing or bearings.	11. Replace gear, bearings, and shaft.
12. Worn output shaft pilot bearing.	12. Replace rollers, replace shafts if necessary.
13. Input shaft bearing retainer loose.	13. Tighten retainer.
14. Other parts striking shift linkage.	14. Make adjustments to provide clearance.
15. Worn input or output shaft bearings.	15. Replace bearings.
16. Worn input shaft bushing in flywheel.	16. Replace bushing or bearing.
17. Bent output shaft.	17. Replace shaft.

PROBLEM: NOISY — ALL GEARS

Possible Cause	Correction
1. Insufficient lubrication.	1. Fill to filler plug.
2. Worn or damaged bearings.	2. Replace bearings.
3. Worn or damaged gears.	3. Replace gears.
4. Wrong lubricant.	4. Drain and fill with recommended lubricant.
5. Excessive sychronizer wear.	5. Replace synchronizer.
6. Defective speedometer drive gears.	6. Replace gears.
7. Transmission misaligned.	7. Correct alignment.
8. Excessive input or output shaft and/or countergear end play.	8. Adjust end play.
9. Contaminated lubricant.	9. Disassemble clean and repair transmission.

PROBLEM: NOISY IN NEUTRAL — ENGINE RUNNING

Possible Cause	Correction
1. Worn or damaged input shaft bearing.	1. Replace bearing.
2. Worn or damaged gears.	2. Replace gears.
3. Lack of lubrication.	3. Fill to level of filler plug.
4. Countershaft bearings worn or damaged.	4. Replace bearings, countergear, and shaft.
5. Output shaft pilot bearing worn or damaged.	5. Replace all rollers.
6. Countergear antilash plate worn or damaged.	6. Replace plate or countergear as required.
7. Lubricant contaminated with broken bits of gears, bearings, or other parts.	7. Disassemble, clean, and repair transmission.

PROBLEM: NOISY — HIGH GEAR

Possible Cause	Correction
1. Defective input shaft bearing.	1. Replace bearing.
2. Defective output shaft bearing.	2. Replace output shaft bearing.
3. Defective synchronizer.	3. Replace synchronizer.
4. Defective speedometer drive gears.	4. Replace speedometer drive gears.

PROBLEM: NOISY — SECOND GEAR (THREE SPEED)

Possible Cause	Correction
1. Countergear rear bearings worn or damaged.	1. Replace countergear bearings. Replace shaft and countergear if needed.
2. Defective synchronizer.	2. Replace synchronizer.
3. Constant mesh second speed gear loose on shaft.	3. Replace gear and/or shaft.
4. Constant mesh second speed gear teeth worn or chipped.	4. Replace second speed gear.

PROBLEM: NOISY — LOW AND REVERSE

Possible Cause	Correction
1. Countergear low and reverse gear worn or damaged.	1. Replace countergear.
2. Low and reverse sliding gear defective.	2. Replace low and reverse sliding gear.
3. Reverse idler gear or synchromesh low gear defective.	3. Replace reverse idler or synchromesh low gear.

PROBLEM: NOISY — REVERSE

Possible Cause	Correction
1. Reverse idler bushings worn.	1. Replace idler gear or bushings.
2. Reverse idler gear worn or damaged.	2. Replace reverse idler gear.
3. Countergear reverse gear worn or damaged.	3. Replace countergear.
4. Defective reverse sliding gear (synchromesh low gear).	4. Replace reverse sliding gear.

PROBLEM: STICKS IN GEAR

Possible Cause	Correction
1. Insufficient lubricant.	1. Fill to filler plug.
2. Synchronizer clutch sleeve teeth burred.	2. Replace synchronizer.
3. Sticking shift rails.	3. Free and lubricate.
4. Synchronizer blocking ring stuck to mating gear.	4. Free, lubricate, or replace blocking ring or mating gear.
5. Shift linkage defective.	5. Repair or replace linkage.
6. Insufficient clutch pedal free travel.	6. Adjust free travel.
7. Transmission misaligned.	7. Correct alignment.

PROBLEM: GEAR CLASH — SHIFTING FROM NEUTRAL TO LOW OR REVERSE

Possible Cause	Correction
1. Insufficient clutch pedal free travel.	1. Adjust free travel.
2. Wrong lubricant.	2. Drain and fill with correct lubricant.
3. Engine rpm too high.	3. Set to correct idle rpm.
4. Driver not waiting long enough after depressing clutch.	4. Instruct driver.
5. Sticking input shaft clutch pilot bearing.	5. Replace pilot bearing.

PROBLEM: LOSS OF LUBRICANT

Possible Cause	Correction
1. Cover loose.	1. Tighten cover.
2. Cover gasket loose or defective.	2. Tighten cover and/or replace gasket.
3. Input shaft bearing retainer loose, broken, or gasket defective.	3. Tighten retainer, replace gasket or retainer.
4. Input shaft bearing retainer seal defective.	4. Replace seal.
5. Output shaft seal worn.	5. Replace seal.
6. Countershaft loose in case.	6. Replace case.
7. Lubricant level too high.	7. Drain to level of filler plug.
8. Shaft expansion plugs loose in case.	8. Replace plugs. Use sealer.
9. No sealer on bolt threads.	9. Seal threads.
10. Damage shift shaft seal.	10. Replace seal.
11. Vent plugged.	11. Open vent.
12. Wrong lubricant.	12. Drain and refill with recommended lubricant.
13. Cracked case or extension housing.	13. Replace case or housing.
14. Drain or filler plug loose.	14. Tighten plug.

FREEWHEEL TYPE OVERDRIVE DIAGNOSIS

PROBLEM: OVERDRIVE WILL NOT ENGAGE

Possible Cause	Correction
1. Dash control fails to move overdrive lockup lever to proper position.	1. Adjust control.
2. Relay fuse blown.	2. Replace. Check for reason.
3. If no relay is used, circuit fuse blown.	3. Replace. Check for reason.
4. Relay inoperative.	4. Replace relay.
5. Governor inoperative.	5. Replace governor.
6. Kickdown switch defective or improperly adjusted.	6. Replace or adjust switch.
7. Solenoid inoperative.	7. Replace solenoid.
8. Solenoid installed incorrectly.	8. Install correctly.
9. Wiring loose, disconnected, shorted, corroded, or open.	9. Clean, attach, and tighten. Replace faulty wires.
10. Balk ring open end installed away from pawl.	10. Install balk ring opening in line with pawl.
11. Overdrive misaligned with transmission.	11. Loosen overdrive-to-transmission fasteners. Tap adapter until shift rail moves freely. Tighten fasteners.

PROBLEM: ROUGH ENGAGEMENT

Possible Cause	Correction
1. Insufficient balk ring tension.	2. Install new balk ring-hub assembly.

PROBLEM: OVERDRIVE ENGAGES BUT WILL NOT DRIVE UNLESS LOCKED OUT MANUALLY

Possible Cause	Correction
1. Roller clutch retainer springs weak or installed incorrectly.	1. Install properly or replace.
2. Roller clutch cam surface worn.	2. Replace clutch unit.
3. Roller clutch rollers worn or broken.	3. Replace all rollers.

PROBLEM: FREE-WHEELS ABOVE 20 TO 30 MPH (40.2 TO 48.3 Km/h)

Possible Cause	Correction
1. Overdrive will not engage.	1. (See OVERDRIVE WILL NOT ENGAGE.)

PROBLEM: OVERDRIVE WILL NOT KICKDOWN

Possible Cause	Correction
1. Defective kickdown switch.	1. Replace kickdown switch.
2. Improperly adjusted kickdown switch.	2. Adjust switch.
3. Dirty solenoid ground out contacts.	3. Clean or replace contact assembly.
4. Wire between kickdown switch and solenoid loose, corroded, or open.	4. Clean and tighten. Replace if needed.
5. Wire between kickdown switch and coil loose, corroded,or open.	5. Clean and tighten. Replace if needed.

PROBLEM: ENGINE STOPS WHEN KICKDOWN SWITCH IS PRESSED

Possible Cause	Correction
1. Kickdown switch shorted.	1. Replace switch.
2. Wire from kickdown to solenoid grounded.	2. Insulate wire.

PROBLEM: ENGINE STOPS

Possible Cause	Correction
1. Wire between kickdown switch and coil grounded.	1. Insulate wire.
2. Kickdown switch grounded.	2. Replace switch.

PROBLEM: NO REVERSE DRIVE

Possible Cause	Correction
1. Shift rail binding.	1. Loosen overdrive-to-transmission fasteners. Tap adapter to free shift rail. Torque fasteners.

PROBLEM: OVERDRIVE WILL NOT RELEASE

Possible Cause	Correction
1. Grounded governor switch.	1. Replace.
2. Wire from relay to governor grounded.	2. Insulate wire.
3. Defective relay.	3. Replace relay.
4. Pawl stuck.	4. Free pawl.
5. Solenoid stuck.	5. Free solenoid.
6. Gears jammed.	6. Free gears.
7. Control cable disconnected.	7. Connect cable and adjust.

CONSTANT DRIVE TYPE OVERDRIVE DIAGNOSIS

PROBLEM: OVERDRIVE WILL NOT ENGAGE

Possible Cause	Correction
1. Defective switch or open wire in control circuit.	1. Check for loose or broken wire, blown fuse, defective switch. Clean, connect, or replace as needed.
2. Lube level low.	2. Add lube as required.
3. Solenoid valve sticking or grounded.	3. Clean, test, replace if needed.
4. Sliding clutch sticking. Broken clutch return springs. Internal leaks. Pump worn. Worn sliding clutch friction lining. Leaking apply piston seals. Misaligned pump.	4. Remove. Disassemble. Repair as needed.
5. Plugged filters. Broken relief valve assembly. Control orifice plugged. Relief valve sticking.	5. Operate car. Engage overdrive and test pressure. If below recommended level, remove pan, filters, and valves. Clean. Replace plugged filters, O-ring seals, valves with broken springs. Clean solenoid valve control orifice with air.

PROBLEM: OVERDRIVE WILL NOT DISENGAGE

SPECIAL WARNING! If overdrive will not disengage — do not attempt to place car in reverse. To do so could ruin the overdrive unit. Repair at once.

Possible Cause	Correction
1. Solenoid valve shorted or stuck.	1. Clean. Test and replace if needed.
2. Shorted wire or closed switch.	2. Check wires and switch. Repair or replace as needed.
3. Relief valve piston stuck. Assemble spring broken. Plugged orifice.	3. Clean. Test and replace if needed.
4. Sticking sliding clutch. Broken or seized gears.	4. Disassemble. Clean. Repair or replace as needed.

PROBLEM: KNOCKING SOUND

Possible Cause	Correction
1. Pump body not installed properly.	1. Remove pump body and align properly in case bore. (Flat should be aligned with oil hole.)

PROBLEM: SLOW DISENGAGEMENT OR OVERDRIVE FREEWHEELS ON OVERRUN

Possible Cause	Correction
1. Solenoid valve sticking. Oil feed holes plugged.	1. Remove. Clean. Test.
2. Control orifice plugged.	2. Remove relief valve piston valve assembly, etc. Remove solenoid valve and clean orifice.
3. Relief valve pistons sticking.	3. Remove. Clean. Replace if scored or pitted.
4. Worn friction lining. Worn brake ring. Overrunning clutch worn or stuck. Worn sun gear. Worn sliding clutch hub.	4. Remove. Disassemble. Inspect parts and replace where needed.

PROBLEM: NO KICKDOWN

Possible Cause	Correction
1. Kickdown switch broken, shorted, or stuck.	1. Replace switch.
2. Improper kickdown switch adjustment.	2. Adjust correctly.
3. Loose, corroded, or broken wire.	3. Clean. Tighten or repair.

PROBLEM: OVERDRIVE SLIPS UPON ENGAGEMENT

Possible Cause	Correction
1. Plugged pressure or pan filter.	1. Clean. Replace if needed.
2. Lube level low.	2. Fill to required level.
3. Control orifice plugged. Relief valve assembly spring broken. Sticking nonreturn valve.	3. Clean. Inspect and replace as required.
4. Loose solenoid terminal wire. Solenoid valve sticking.	4. Clean and tighten connection. Clean valve. Replace if required.
5. Worn friction material on sliding clutch. Worn clutch apply piston seals.	5. Replace as needed.
6. Pump body and oil feed slot in case bore misaligned.	6. Disassemble. Assemble correctly.

PROBLEM: NOISY WHEN ENGAGED

Possible Cause	Correction
1. Broken, worn, chipped, etc., parts. Sliding clutch slipping.	1. Disassemble. Clean. Repair or replace parts as needed.

SPECIAL NOTE! Not all constant drive overdrives are exactly alike. The foregoing problems and corrections are typical of most and provide a general guide only.

TRANSFER CASE (PART-TIME DRIVE) DIAGNOSIS

PROBLEM: JUMPS OUT OF GEAR IN TWO-WHEEL DRIVE

Possible Cause	Correction
1. Shift lever detent spring weak or broken.	1. Replace spring.
2. Sliding clutch spline engaging surface worn or tapered.	2. Replace worn parts.

PROBLEM: JUMPS OUT OF GEAR IN FOUR-WHEEL DRIVE

Possible Cause	Correction
1. Shift lever interference with floor pan.	1. Provide proper clearance.
2. Excessive transfer case movement.	2. Check and replace mounts if needed.
3. Sliding clutch engaging surfaces tapered or worn.	3. Replace worn parts.
4. Bent shift fork.	4. Replace fork.
5. Shift rod detent spring weak or broken.	5. Replace spring.
6. Shift lever torsion spring (where used) not holding.	6. Replace spring.
7. Worn bearings, gear teeth, shafts, etc.	7. Overhaul case.

PROBLEM: NOISE

NOTE: Transfer cases using a gear setup, such as shown in Fig. 27-84, produce considerable gear whine which is normal.

Possible Cause	Correction
1. Worn bearings, splines, chipped gears, worn shafts, etc.	1. Rebuild case.
2. Low lube level.	2. Fill to proper level.
3. Loose mounts.	3. Tighten or replace if needed.

TRANSFER CASE (FULL-TIME) PROBLEM DIAGNOSIS

PROBLEM: NOISY OPERATION

Possible Cause	Correction
1. Lube level low.	1. Fill to correct level.
2. Operating in ''lockout'' on hard, dry surface roads.	2. Shift out of ''lockout.''
3. Improper lubricant.	3. Drain and fill with recommended lube.
4. ''Slip-stick'' condition (''Quadra-Trac'' type). Makes a grunting, pulsating, rasping sound.	4. Normal if vehicle has not been driven for a week or two. Should stop after some usage. If it persists, drain fluid and refill. Use special additive if required. Make certain tire sizes are the same and pressures are equal.
5. Excessive wear on gears, chains, differential unit, etc.	5. Rebuild case as needed.
6. Loose or deteriorated mounts.	6. Tighten or replace.

PROBLEM: JUMPS OUT OF LOW RANGE AND/OR IS HARD TO SHIFT INTO OR OUT OF LOW RANGE

Possible Cause	Correction
1. Shift linkage improperly adjusted, bent, or broken.	1. Adjust correctly. Straighten or replace.
2. Shift rails dry or scored.	2. Clean. Polish. Lube or replace as needed.
3. Improper driver operation.	3. Follow shift procedure recommended by manufacturer.
4. Reduction unit parts worn or damaged.	4. Repair as needed.

PROBLEM: EMERGENCY DRIVE (LOCKOUT) WILL NOT ENGAGE

Possible Cause	Correction
1. Lockout parts damaged.	1. Repair as needed.
2. Defective vacuum control. Loose or damaged vacuum lines (''Quadra-Trac'').	2. Replace control. Replace or connect vacuum hoses.
3. Defective shift linkage.	3. Repair or replace.

PROBLEM: WILL NOT ENGAGE IN TWO-WHEEL DRIVE

Possible Cause	Correction
1. No vacuum. Loose or broken hoses.	1. Replace hoses. Secure all loose connections.
2. Defective shift motor (axle).	2. Replace motor.
3. Defective shift motor (transfer case).	3. Replace motor.

PROBLEM: WILL NOT ENGAGE IN FOUR-WHEEL DRIVE

Possible Cause	Correction
1. No vacuum. Loose or broken hoses.	1. Replace hoses. Secure all loose connections.
2. Defective axle shift motor.	2. Replace motor.
3. Binding or broken transfer case shift linkage.	3. Repair or replace the linkage.
4. Defective axle shift linkage.	4. Repair or replace linkage.
5. Damaged transfer case.	5. Repair or replace transfer case.

PROBLEM: LUBRICANT LEAKAGE

Possible Cause	Correction
1. Clogged breather vent in transmission and/or transfer case.	1. Open clogged vent(s).
2. Lube level too high in transmission and/or transfer case.	2. Lower to the correct level.
3. Improper lubricant or viscosity.	3. Drain and fill with proper lubricant.
4. Defective seals, worn bearings, and/or shaft.	4. Replace worn parts.
5. Porous case area.	5. Clean and repair area per maker's instructions.
6. Transfer case-to-transmission bolts loose.	6. Tighten. Replace seal if necessary. Check lube level.

PROBLEM: VEHICLE WANDERS WHEN DRIVING STRAIGHT AHEAD

Possible Cause	Correction
1. Improperly matched tire size (all must be same diameter) rolling radius.	1. Use a matched set of tires.
2. Uneven tire pressure.	2. Air to recommended levels.

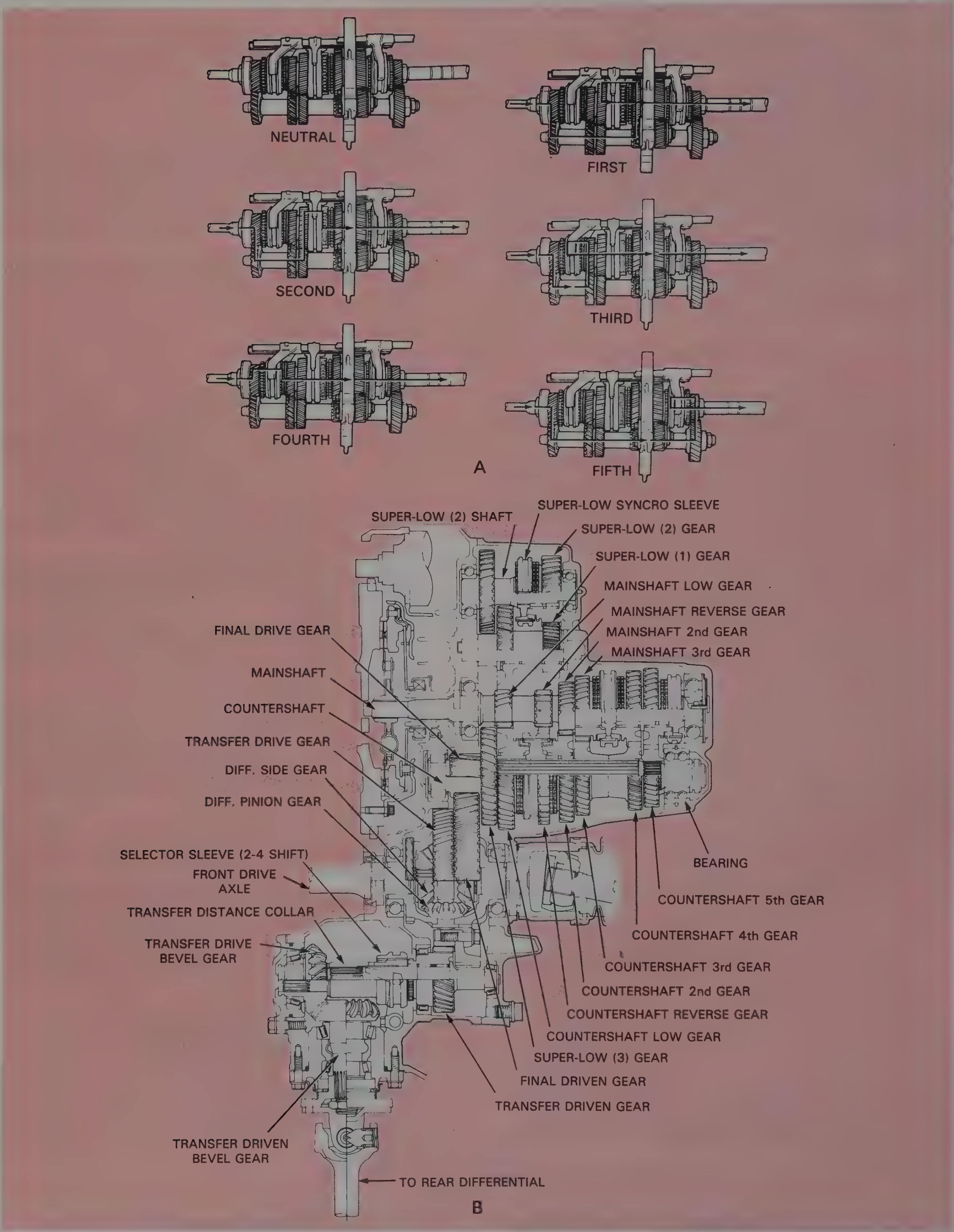
KNOW THESE TERMS

Synchromesh, Drive ratio, Transaxle, Extension housing, Input shaft, Output shaft, Countershaft, Antilash plate, Synchronizer, Snap ring, Staking a pin, Dummy shaft, Blocking ring, Shift fork, Shift lever, Overdrive transmission, Freewheeling, Overdrive, Planetary gears, Roller clutch, Solenoid, Pawl, Balk ring, Governor, Annulus gear, Four-wheel drive, Full-time four-wheel drive, Transfer case, Low range, High range, "Quadra-Trac", Limited-slip differential, Viscous coupling, Vacuum motor, Emergency drive lockout, Part-time four-wheel drive.

QUIZ - Chapter 27

1. An average ratio for low or first gear in a three speed transmission might be 5.69 to 1. True or False?
2. A four speed transmission gives a much lower first gear ratio than does the three speed. True or False?
3. It is important to talk the owner before road testing.
4. Clutch adjustment can affect transmission shifting. True or False?
5. Before road testing, always check the lubricant level in the transmission.
6. Before disconnecting a universal joint, Mark the shaft and U-joint yoke or flange to assure correct assanbly.
7. Most car transmissions are light enough to be removed without a jack or pilot bolts. True or False?
8. All transmissions disassemble in the same manner. True or False?
9. After transmission removal, but before disassembly, what checks should be made? List five.
10. When a hammer is required, use one with a rawhide hammer.
11. Snap rings may be reused with no trouble. True or False?
12. Always Check change all oil seals.
13. After cleaning, check the transmission case and extension housing for crans.
14. A gear should never be reused if the teeth show any signs of:
    a. Chipping.
    b. Galling.
    c. Excessive wear.
    d. Any of the above.
15. List six inspection points for the input shaft assembly.
16. List six inspection points for the output shaft assembly.
17. List six inspection points for the countergear assembly.
18. The countershaft is often held in place by:
    a. A lock pin.
    b. A lock plate.
    c. Staking.
    d. Both a and b.
19. Some reverse idler gears use bronze bushings. True or False?
20. Pay attention to the bloking rings when assembling the synchronizer sleeve on the hub.
21. Synchronizer insert springs should be installed with:
    a. Both on one side.
    b. The free ends up.
    c. The free ends down.
    d. ~~One on each side.~~
22. New parts should be checked for dusing, siz and shape.
23. Old gaskets may be reused successfully providing they are not split. True or False?
24. When a transmission has suffered heavy damage, check gears, shafts, and case for craking. ✓
25. A dommy shaft greatly facilitates countergear shaft installation.
26. Use Softi grease to hold needle or roller bearings and thrust washers in place during assembly.
27. When using the above to hold needle bearings, etc., in place, be careful to avoid plug the lubricant entrance hole.
28. Fastener length is unimportant providing the thread size and diameter is correct. True or False?
29. Before adjusting the length of the shift linkage rods, both the shift column slever and the transmission Shift lever must be in Neutral.
30. The transmission should be filled even with the countergear with the recommended grade of lubricant.
31. When removing or installing, never allow the weight of the transmission to hang on the input shaft.
32. Before condemning the overdrive unit (freewheeling type), check the Mechanical controls and the electrical system.
33. Some cars permit certain types of overdrive units to be removed while the transmission is in the car. True or False?
34. Is it possible to remove the overdrive without dismantling the transmission?
    a. Never.
    b. Sometimes.
    c. Always.
35. On a freewheeling overdrive, list seven things to be checked during the overdrive inspection.

    gear teeth, roller clutch cam cam a
36. Allowing the adapter plate (freewheel overdrive)


NEUTRAL
FIRST
SECOND
THIRD
FOURTH
FIFTH
A
SUPER-LOW (2) SHAFT
SUPER-LOW SYNCRO SLEEVE
SUPER-LOW (2) GEAR
SUPER-LOW (1) GEAR
MAINSHAFT LOW GEAR
MAINSHAFT REVERSE GEAR
MAINSHAFT 2nd GEAR
MAINSHAFT 3rd GEAR
FINAL DRIVE GEAR
MAINSHAFT
COUNTERSHAFT
TRANSFER DRIVE GEAR
DIFF. SIDE GEAR
DIFF. PINION GEAR
SELECTOR SLEEVE (2-4 SHIFT)
FRONT DRIVE AXLE
TRANSFER DISTANCE COLLAR
TRANSFER DRIVE BEVEL GEAR
BEARING
COUNTERSHAFT 5th GEAR
COUNTERSHAFT 4th GEAR
COUNTERSHAFT 3rd GEAR
COUNTERSHAFT 2nd GEAR
COUNTERSHAFT REVERSE GEAR
COUNTERSHAFT LOW GEAR
SUPER-LOW (3) GEAR
FINAL DRIVEN GEAR
TRANSFER DRIVEN GEAR
TRANSFER DRIVEN BEVEL GEAR
TO REAR DIFFERENTIAL
B

A—Power flow through a five-speed transmission. B—Cutaway view of a five-speed manual transaxle with integral transfer case for sending power to rear wheels when four-wheel drive is selected. (Chevrolet) to pull away from the transmission can cause the output shaft pilot upend' - Pull and pot to fall into the case.

37. The constant drive overdrive differs from the freewheeling type in several ways. List two significant differences. Hydrolic Mechanical

38. The constant drive overdrive depends upon hydraulic pressure to function. True or False?

39. The sliding clutch in the constant drive overdrive should never be Whashes in Solvent when cleaning.

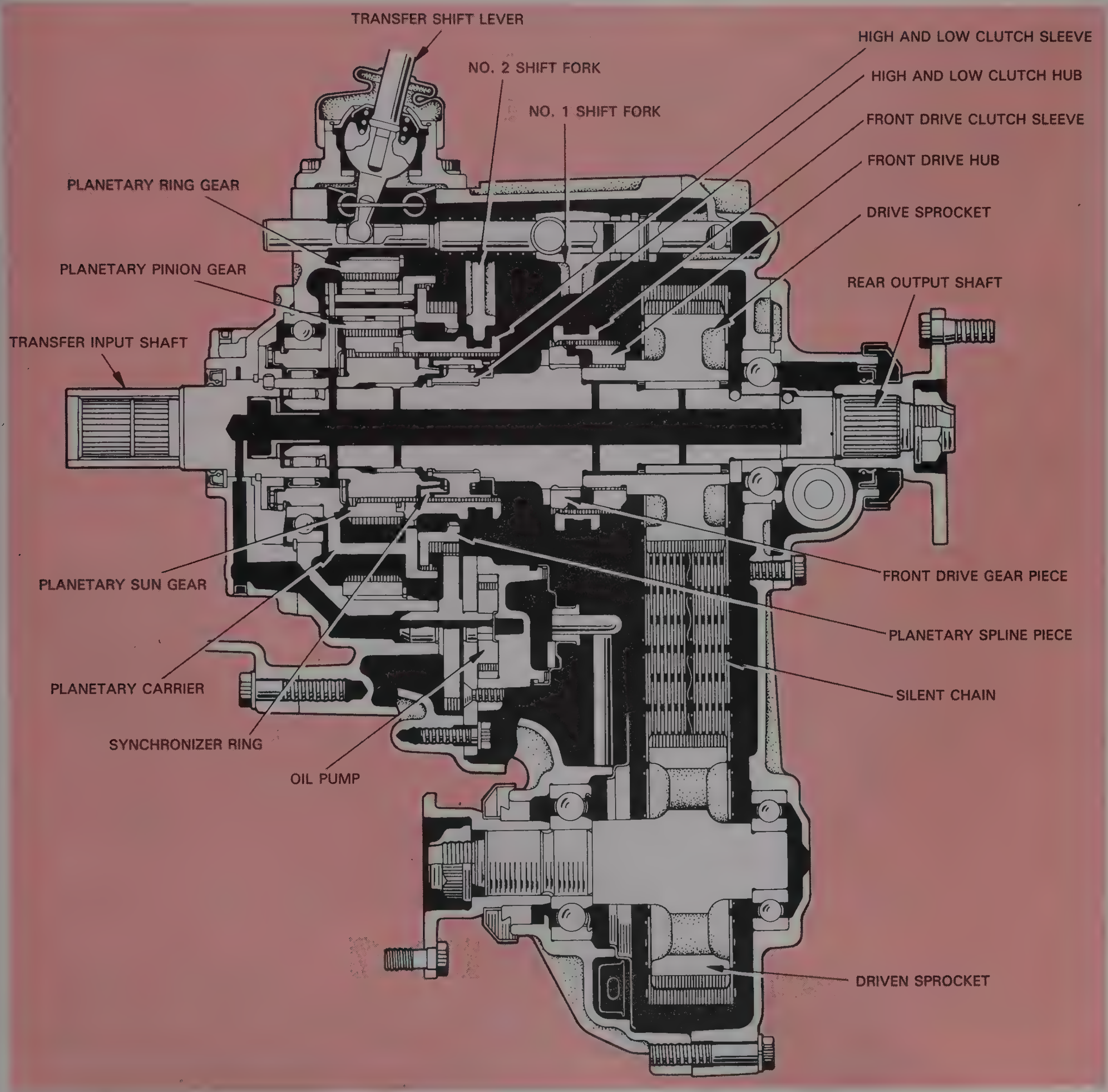
40. Explain the need for a transfer case. fron

41. Full-time four-wheel drive vehicles should be driven in "lockout" when operating on hard, dry roads. True or False?

42. Some transfer cases have only a Low range while others have both a High and low range.

43. One type of transfer case uses a viscous coupling filled with silicone fluid.

44. A vacuum motor may be used to shift a transfer case in and out of four-wheel drive. True or False?


TRANSFER SHIFT LEVER
NO. 2 SHIFT FORK
NO. 1 SHIFT FORK
HIGH AND LOW CLUTCH SLEEVE
HIGH AND LOW CLUTCH HUB
FRONT DRIVE CLUTCH SLEEVE
FRONT DRIVE HUB
DRIVE SPROCKET
REAR OUTPUT SHAFT
PLANETARY RING GEAR
PLANETARY PINION GEAR
TRANSFER INPUT SHAFT
PLANETARY SUN GEAR
PLANETARY CARRIER
SYNCHRONIZER RING
OIL PUMP
FRONT DRIVE GEAR PIECE
PLANETARY SPLINE PIECE
SILENT CHAIN
DRIVEN SPROCKET

Cutaway view of a two speed, part-time transfer case. This case uses a planetary gear reduction setup, along with a drive chain. Low range reduction is 2.566:1. (Toyota)

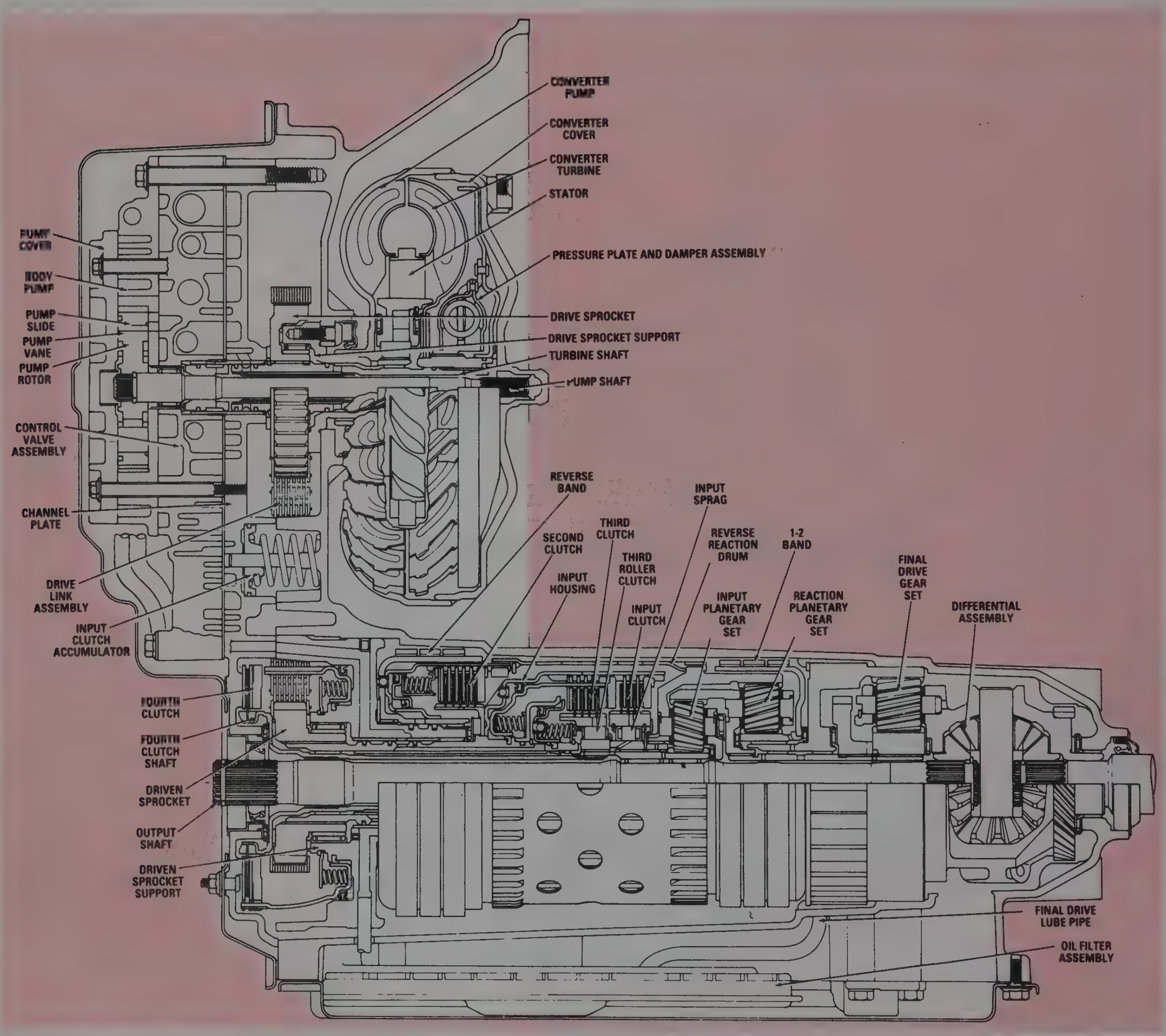
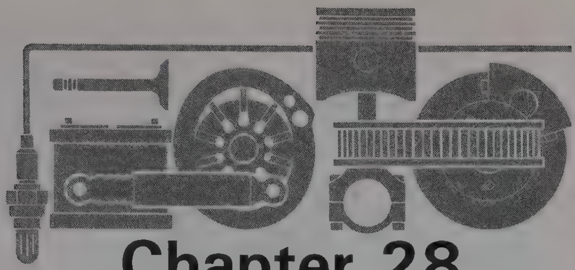

CONVERTER PUMP
CONVERTER COVER
CONVERTER TURBINE
STATOR
PRESSURE PLATE AND DAMPER ASSEMBLY
DRIVE SPROCKET
DRIVE SPROCKET SUPPORT
TURBINE SHAFT
PUMP SHAFT
PUMP COVER
BODY PUMP
PUMP SLIDE
PUMP VANE
PUMP ROTOR
CONTROL VALVE ASSEMBLY
CHANNEL PLATE
DRIVE LINK ASSEMBLY
INPUT CLUTCH ACCUMULATOR
REVERSE BAND
INPUT SPRAG
THIRD CLUTCH
SECOND CLUTCH
REVERSE REACTION DRUM
1-2 BAND
THIRD ROLLER CLUTCH
INPUT HOUSING
FINAL DRIVE GEAR SET
INPUT CLUTCH
INPUT PLANETARY GEAR SET
REACTION PLANETARY GEAR SET
DIFFERENTIAL ASSEMBLY
FOURTH CLUTCH
FOURTH CLUTCH SHAFT
DRIVEN SPROCKET
OUTPUT SHAFT
DRIVEN SPROCKET SUPPORT
FINAL DRIVE LUBE PIPE
OIL FILTER ASSEMBLY

Fig. 28-1. Cutaway view of a four-speed, automatic transaxle. Study all parts and their names. (Cadillac)



Chapter 28

AUTOMATIC TRANSMISSION/TRANSAXLE SERVICE

After studying this chapter, you will be able to:
- ☐ Explain automatic transmission in-car service and diagnosis.
- ☐ Summarize the adjustment of automatic transmission linkage.
- ☐ Describe common automatic transmission testing tools and equipment.
- ☐ Explain automatic transmission shift point and band adjustment.
- ☐ Summarize automatic transmission removal and installation.
- ☐ List common automatic transmission problems and corrections.
- ☐ Road test an automatic transmission.
- ☐ Explain towing procedures for cars with automatic transmissions.

Although progress in automatic transmission design has produced a more compact and simplified unit, the overall mechanism still remains relatively complex.

Variations in basic design, control units, test methods, adjustment, disassembly and assembly techniques, part clearances, and yearly changes all combine to further complicate service. Look at Fig. 28-1.

Obviously, it is not within the scope of a general text to cover complete transmission/transaxle service and repair. Hundreds of pages would be needed to provide complete overhaul, test, and adjustment details for the various types and year models of transmissions.

IN-CAR SERVICE AND PROBLEM DIAGNOSIS

This chapter will be confined to typical in-car service (service that can be performed with transmission in car) and problem diagnosis. Actually, a large percentage of transmission problems can be solved by in-car adjustment and repair. Transmission removal and installation will also be covered.

Both coverage and instructions will apply to typical transmissions. For instructions relating to a specific unit, always refer to the manufacturer's service manual. The manual will provide complete disassembly, inspection, and assembly details. Exploded views, Fig. 28-2, and numerous illustrations covering the various steps are usually shown.

AUTOMATIC TRANSMISSION BASIC DESIGN

Current practice in automatic transmission design utilizes a torque converter, compound planetary gearset, two or more disc clutches, and one or more bands to provide either a two, three, or four speed setup.

The typical torque converter may utilize either a fixed or variable pitch (two stage) stator. In addition, many torque converters are designed to "lock up" when shifted into high. The locking action provides direct, no-slip drive for increased fuel economy and positive

Fig. 28-1 illustrates a Cadillac, four speed, automatic transaxle. Note that this transaxle includes a torque converter with a lock-up pressure plate. Also, note the locations of the various parts, especially the output shaft, differential, clutches, and drive link.

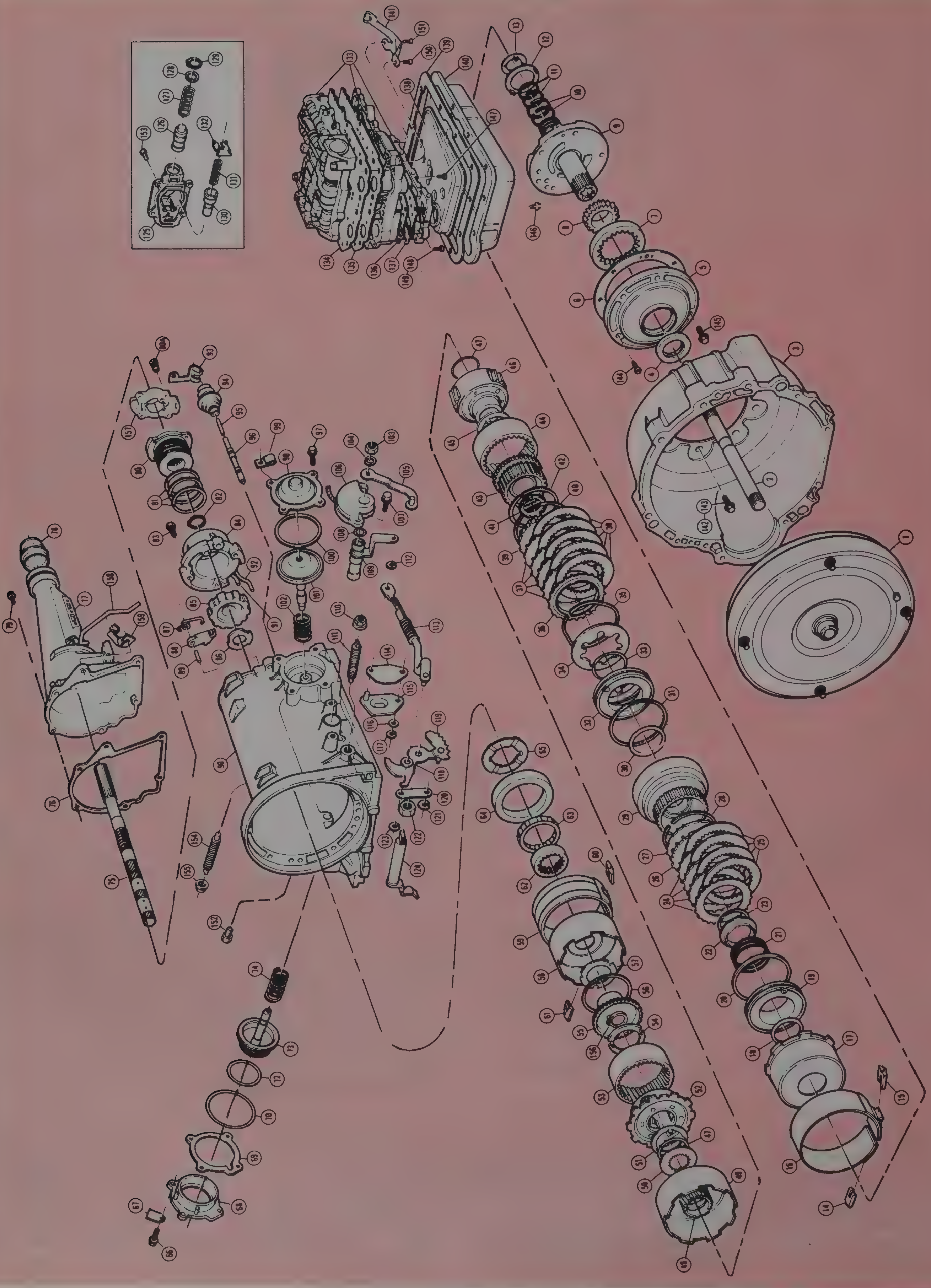
The exploded view in Fig. 28-2 pictures one three speed automatic transmission. Study the names of the various parts, their location in the transmission, and their operational relationship to each other.

Another popular automatic transmission is shown in Fig. 28-4. This four speed arrangement is a Mazda design featuring a torque converter and a planetary gearset.

AUTOMATIC TRANSAXLE—FRONT-WHEEL DRIVE

The transaxle illustrated in Fig. 28-5 is attached directly to the front-wheel drive differential housing. A torque converter drives the transmission through a multiple link chain.

A different automatic transaxle arrangement is illustrated in Fig. 28-6. Torque is transmitted from the transmission to the differential via the output gear



1. Converter Assy.
2. Shaft-Input
3. Housing Converter
4. Seal-Front Oil Pump
5. Body-Front Pump
6. Gasket-Front Oil Pump
7. Gear-Frt. Oil Pump Driven
8. Gear-Frt. Oil Pump Drive
9. Stator Support-Front Oil Pump
10. Seal-Fwd. Cl. Cyl.
11. Seal-Rev. Cl. Cyl.
12. Washer-Front Pump Supt. Thrust
13. Washer-Rev. Cl. Thrust
14. Strut-Intermediate Brake
15. Strut-Intermediate Brake (Anchor Int. Band)
16. Band Assy.-Intermediate
17. Drum Assy.-Intermediate Brake
18. Seal-Rev. Cl. Inner
19. Piston Assy.-High Clutch
20. Seal-High Cl. Outer
21. Spring-High Cl. Piston
22. Retainer-Cl. Piston Spring
23. Ring-2¼ Retaining
24. Plate-Cl. Ext. Spline
25. Plate Assy.
26. Plate-Clutch Pressure
27. Spring-Rev. Cl. Press. Plate Disc
28. Snap Ring (Selective)
29. Cylinder-Fwd. Clutch
30. O-Ring-Cl. Piston Oil Seal
31. Seal-Fwd. Cl. Outer
32. Piston Assy.-Fwd. Clutch
33. Ring-Fwd. Cl. Piston Spring Press.
34. Spring-Fwd. Cl. Piston Disc
35. Ring-Ret. Wave Int.
36. Plate-Fwd. Cl. Press.
37. Plate-Cl. Ext. Spline
38. Plate Assy. Cl. Int. Spline (Friction)
39. Plate-Clutch Pressure
40. Ring-Retaining Ext.
41. Washer-Fwd. Cl. Hub-Thrust
42. Retainer
43. Hub & Bshg. Assy.-Fwd. Cl.
44. Gear-Output Shaft Ring
45. Washer-Rev. Planet Pinion
46. Planet Assy.-Fwd.
47. Retainer
48. Gear-Sun
49. Shell-Input
50. Washer-Input Shell Thrust
51. Washer-Rev. Plt. Carrier-Thrust
52. Planet Assy.-Reverse
53. Gear-Output Shaft Ring
54. Washer-Rev. Drum Thrust
55. Hub-Output Shaft
56. Ring
57. Washer-Rev. Drum Thrust
58. Drum Assy.-Rev. Brake
59. Band Assy.-Reverse
60. Strut-Rev. Brake (Actuates Rev. Band)
61. Strut-Rev. Band (Anchor)
62. Race-Overrun Clutch-Inner
63. Spring & Roller Assy.
64. Race-Overrun Clutch-Outer
65. Washer-Rev. Drum-To-Case – Thrust
66. Bolt
67. Tag-Service Ident.
68. Cover-Interm. Band Servo
69. Gasket-Interm. Band Servo
70. Seal-Interm. Band Servo Cover-Large
72. Seal-Interm. Band Servo Piston-Small
73. Piston Assy. Interm. Band Servo
74. Spring-Interm. Band Servo Piston
75. Shaft Assy.-Output
76. Gasket-Extension
77. Extension Assy.
78. Seal Assy.-Ext. Oil
79. Bolt
80. Body-Gov. Oil Collector
80A. Screen Assy.-Gov. Oil
81. Ring-Governor Seal
82. Screen-Pump Inlet
83. Bolt
84. Sleeve-Oil Distributor
85. Gear-Output Shaft Parking
86. Washer-Output Shaft Thrust
87. Spring-P.P. Return
88. Pawl Assy.-Parking
89. Pin
90. Case Assembly
91. Tube-Oil Distributor
92. Tube-Oil Distributor
93. Clip-Throt. Cntl. Valve Diaphragm
94. Diaphragm Assy.-T.V. Control
95. Rod-T.V. Control
96. Valve-Throttle Control
97. Bolt
98. Cover-Rev. Band Servo
99. Clip-Electrical Wiring Harness
100. Seal-Rev. Band. Servo Piston Cover
101. Piston Assy.-Rev. Band Servo
102. Spring-Rev. Servo Piston
103. Nut
104. Washer
105. Lever Assy.-Dwnshift Control – Outer
106. Switch Assy.-Neutral Start
107. Screw & Washer Assy.
108. Seal-3/8 O-Ring
109. Lever Assy.-Manual Control
110. Nut-Sealer
111. Screw-Adjusting
112. Ring
113. Rod Assy.-Park Lever Actuating
114. Spacer-Parking Lever
115. Lever Assy.-Parking Actuating
116. Washer
117. Ring Retaining
118. Roller-Park Lever Actuating Rod
119. Lever Assy.-Man. Vlv. Detent – Inner
120. Link-P.P. Toggle Oper. Lever
121. Ring
122. Nut
123. Ring
124. Lever Assy.-Dwnshift Detent – Inner
125. Body-Governor Valve
126. Valve-Governor Primary
127. Spring-Gov. Primary Valve
128. Washer
129. Retaining Ring-Internal
130. Valve-Gov. Secondary
131. Spring-Gov. Secondary Valve
132. Retainer-Gov. Sec. Valve Spring
133. Control Assy.-Main
134. Plate-Control Vlv. Body
135. Gasket-Control Valve Body
136. Plate-3-2 Timing Body
137. Gasket-3-2 Timing Body
138. Screen & Grommet Assy.-Oil Pan
139. Gasket-Oil Pan
140. Pan Assy.-Oil Pan
141. Spring Assy.-Man. Vlv. Detent
142. Bolt
143. Bolt
144. Screw
145. Bolt
146. Bolt
147. Screw
148. Screw
149. Screw
150. Screw
151. Screw
152. Plug-Dry Seal Tapped Thread
153. Bolt
154. Screw Adjusting
155. Nut
156. Ring Retainer
157. Body Assy. Governor
158. Tube-Vent
159. Clip

Fig. 28-2. Exploded view of a three speed transmission. (Ford)

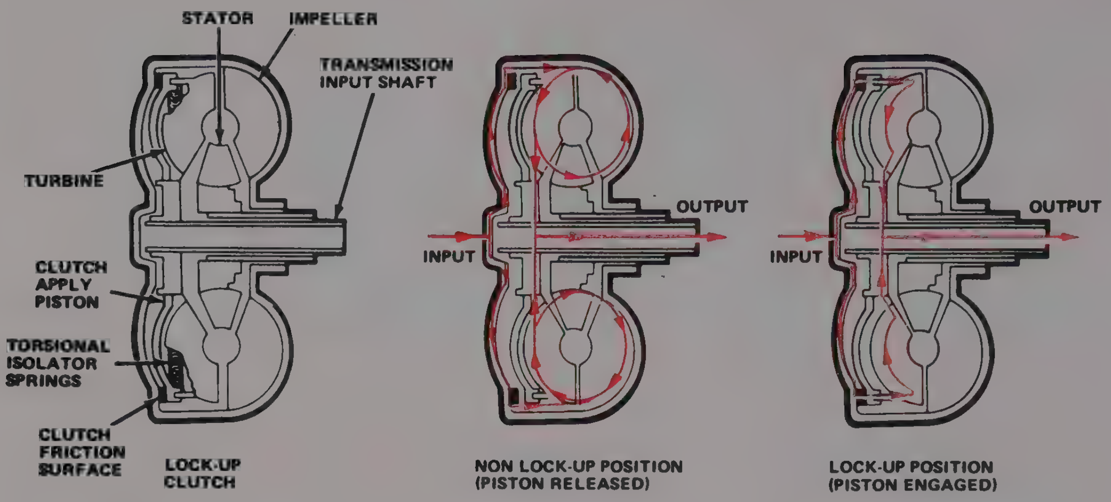

STATOR
IMPELLER
TRANSMISSION INPUT SHAFT
TURBINE
CLUTCH APPLY PISTON
TORSIONAL ISOLATOR SPRINGS
CLUTCH FRICTION SURFACE
LOCK-UP CLUTCH
INPUT
OUTPUT
NON LOCK-UP POSITION (PISTON RELEASED)
INPUT
OUTPUT
LOCK-UP POSITION (PISTON ENGAGED)

Fig. 28-3. Operation of one type of lock-up converter. When in lock-up position, the converter acts as a solid drive unit. (AMC)

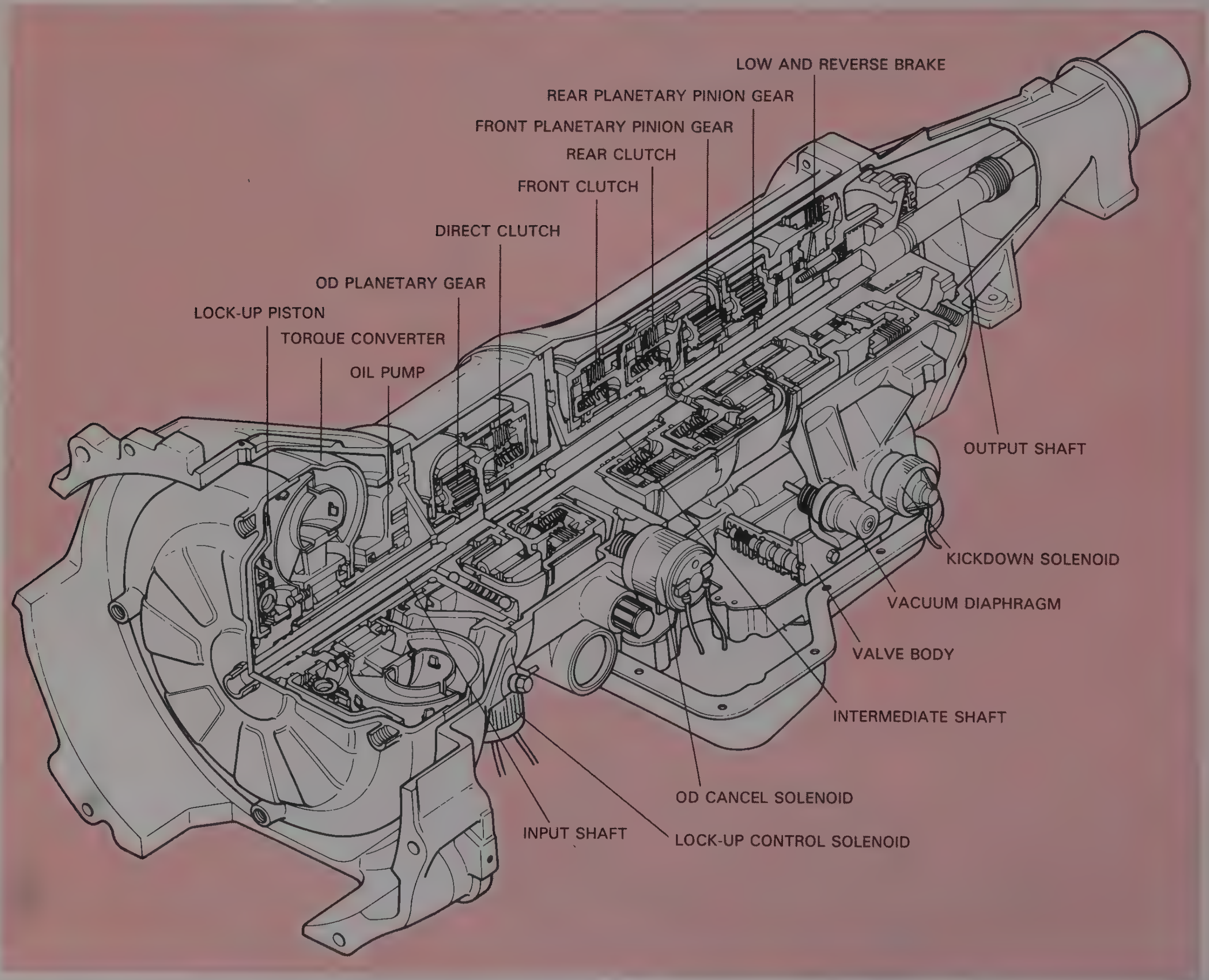

LOW AND REVERSE BRAKE
REAR PLANETARY PINION GEAR
FRONT PLANETARY PINION GEAR
REAR CLUTCH
FRONT CLUTCH
DIRECT CLUTCH
OD PLANETARY GEAR
LOCK-UP PISTON
TORQUE CONVERTER
OIL PUMP
OUTPUT SHAFT
KICKDOWN SOLENOID
VACUUM DIAPHRAGM
VALVE BODY
INTERMEDIATE SHAFT
OD CANCEL SOLENOID
INPUT SHAFT
LOCK-UP CONTROL SOLENOID

Fig. 28-4. Cutaway view of a four speed, overdrive automatic transmission. Overdrive is a .72:1 ratio. (Mazda)

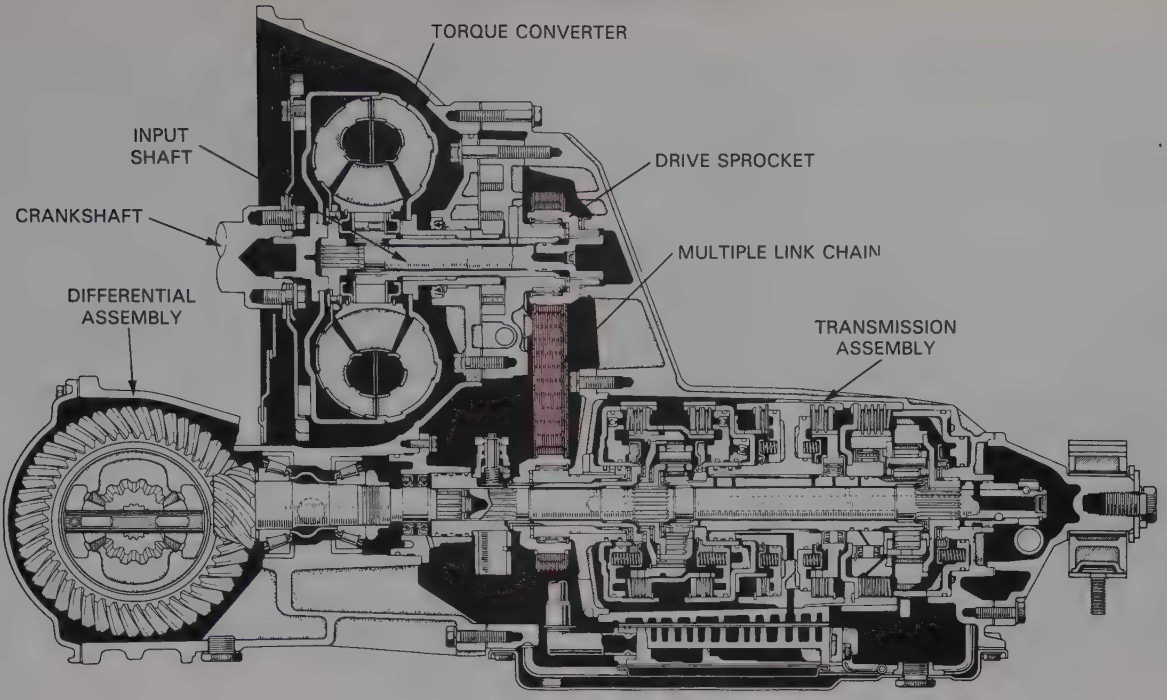
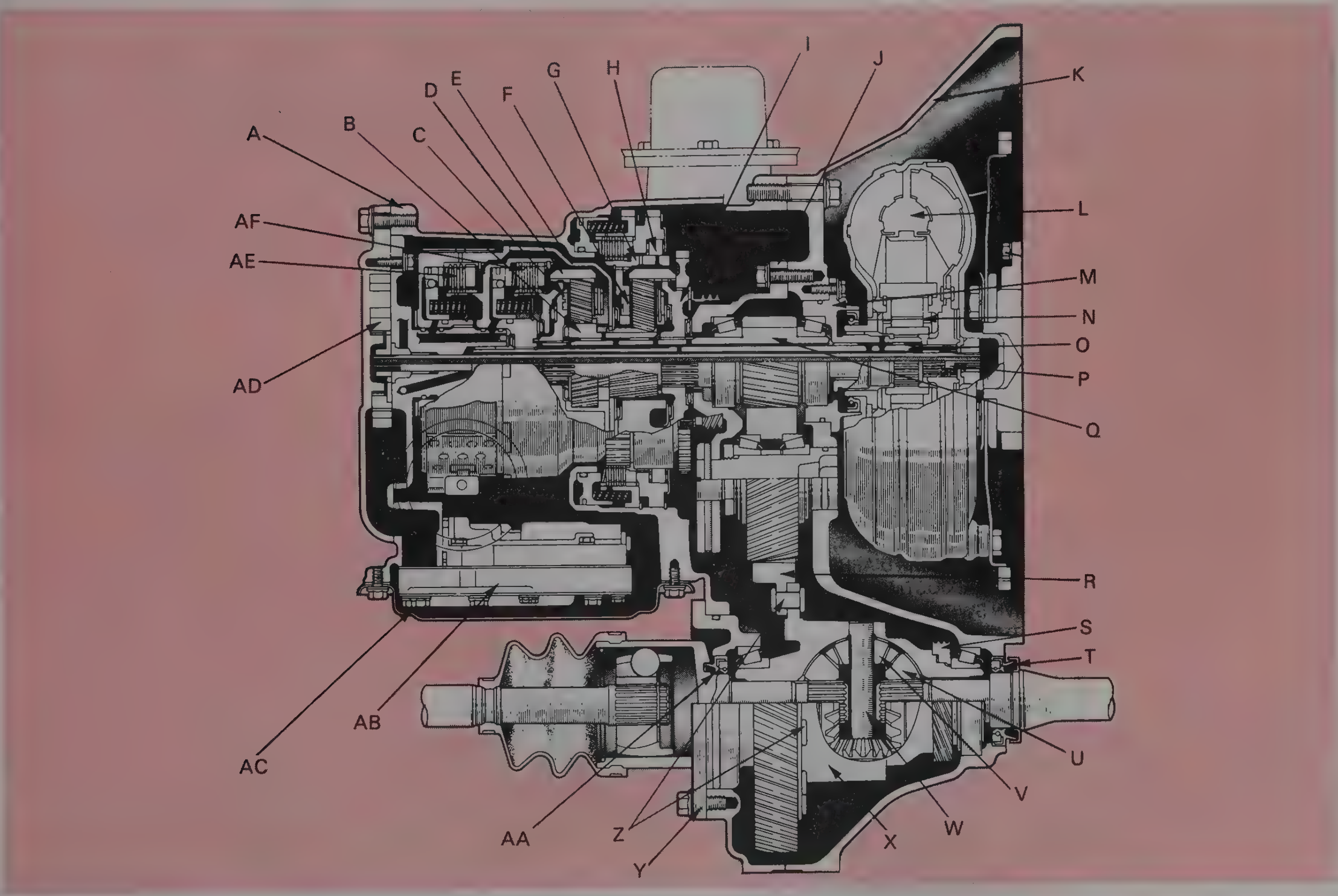

TORQUE CONVERTER
INPUT SHAFT
DRIVE SPROCKET
CRANKSHAFT
MULTIPLE LINK CHAIN
DIFFERENTIAL ASSEMBLY
TRANSMISSION ASSEMBLY

Fig. 28-5. One type of automatic transaxle arrangement. Note that torque from converter is transmitted to the transmission by a multiple link chain. (Toyota)


I
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W
X
Y

Fig. 28-6. Cutaway of a three speed automatic transaxle. Gear ratios are: First—2.841:1; Second—1.541:1; Third—1.000:1; and Reverse—2.400:1. Note that the ring gear (R) is secured to differential gear case with rivets (Z). A—Transmission. B—Sun gear. C—Planetary carrier. D—Rear clutch hub assembly. E—Connection shell (clutch housing). F—Planetary carrier. G—One-way clutch. H—One-way clutch. I—Drum hub assembly. J—Bearing housing. K—Torque converter housing. L—Torque converter. M—Bearing cover. N—Oil seal. O—Turbine shaft. P—Oil pump shaft. Q—Output gear. R—Ring gear. S—Speedometer drive gear. T—Oil seal. U—Side gear. V—Pinion gear. W—Pinion shaft. X—Differential gear case. Y—Side bearing housing. Z—Rivets. AA—Oil seal. AB—Control valve. AC—Oil pan. AD—Oil pump. AE—Front clutch. AF—Rear clutch. (Mazda)

assembly (Q), which meshes directly to the differential ring gear (R).

TRANSMISSION SHIFT ACTION

Fig. 28-7 illustrates clutch, band, and planetary gearset action during the various drive ranges (gears) for a typical three speed automatic. A cross-sectional view of this same transmission is shown in Fig. 28-8.

TRANSMISSION FLUID LEVEL IS VERY IMPORTANT

ALWAYS CHECK TRANSMISSION FLUID LEVEL BEFORE CONDUCTING ANY TESTS. TRANSMISSION OPERATION CAN BE UPSET BY EITHER A HIGH OR LOW FLUID LEVEL.

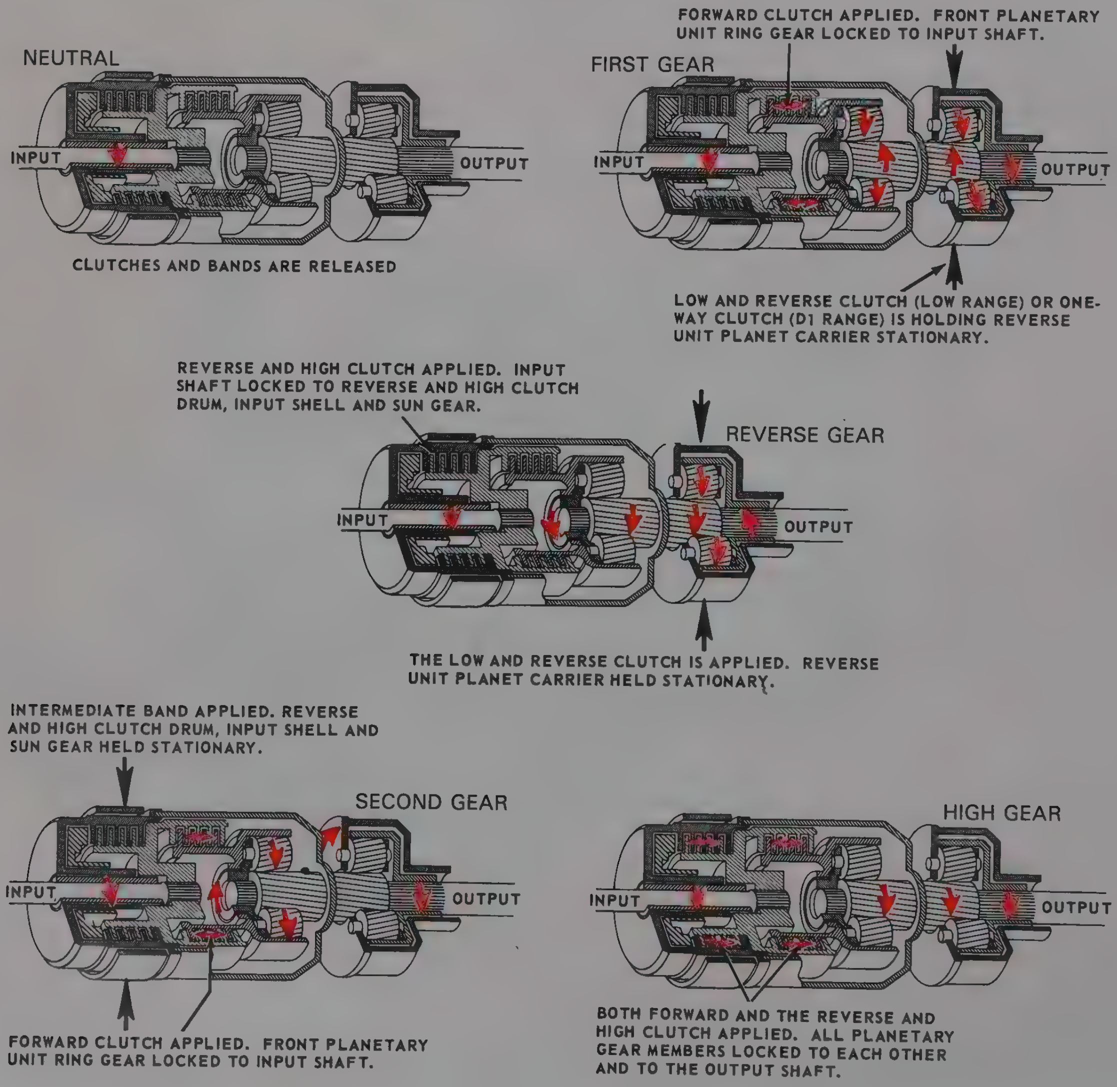
A high level (above FULL mark) will cause foaming with resultant aeration (filling oil with tiny air bubbles). When aerated oil is pumped throughout the transmission, faulty clutch and band operation, overheating, cavitation noise (noise caused by torque converter blades operating in aerated oil), and other problems can result.

Low fluid level can also cause overheating, slipping, and other operational malfunctions.

The fluid level (transmission at operating temperature, shift lever in N or P as needed) should be between the ADD and FULL marks on the dipstick. See Fig. 28-9.

CHECKING FLUID LEVEL

Before checking the fluid level, the transmission fluid must be brought to normal operating temperature (170-200 °F or 77-93 °C). Four or five miles of driving, including frequent stops and starts, will usually produce normal fluid temperature.


NEUTRAL

CLUTCHES AND BANDS ARE RELEASED

FIRST GEAR
FORWARD CLUTCH APPLIED. FRONT PLANETARY UNIT RING GEAR LOCKED TO INPUT SHAFT.

LOW AND REVERSE CLUTCH (LOW RANGE) OR ONE-WAY CLUTCH (D1 RANGE) IS HOLDING REVERSE UNIT PLANET CARRIER STATIONARY.

REVERSE GEAR
REVERSE AND HIGH CLUTCH APPLIED. INPUT SHAFT LOCKED TO REVERSE AND HIGH CLUTCH DRUM, INPUT SHELL AND SUN GEAR.

THE LOW AND REVERSE CLUTCH IS APPLIED. REVERSE UNIT PLANET CARRIER HELD STATIONARY.

SECOND GEAR
INTERMEDIATE BAND APPLIED. REVERSE AND HIGH CLUTCH DRUM, INPUT SHELL AND SUN GEAR HELD STATIONARY.

FORWARD CLUTCH APPLIED. FRONT PLANETARY UNIT RING GEAR LOCKED TO INPUT SHAFT.

HIGH GEAR

BOTH FORWARD AND THE REVERSE AND HIGH CLUTCH APPLIED. ALL PLANETARY GEAR MEMBERS LOCKED TO EACH OTHER AND TO THE OUTPUT SHAFT.

Fig. 28-7. Clutch, band, and gearset action during various drive ranges. (Ford)

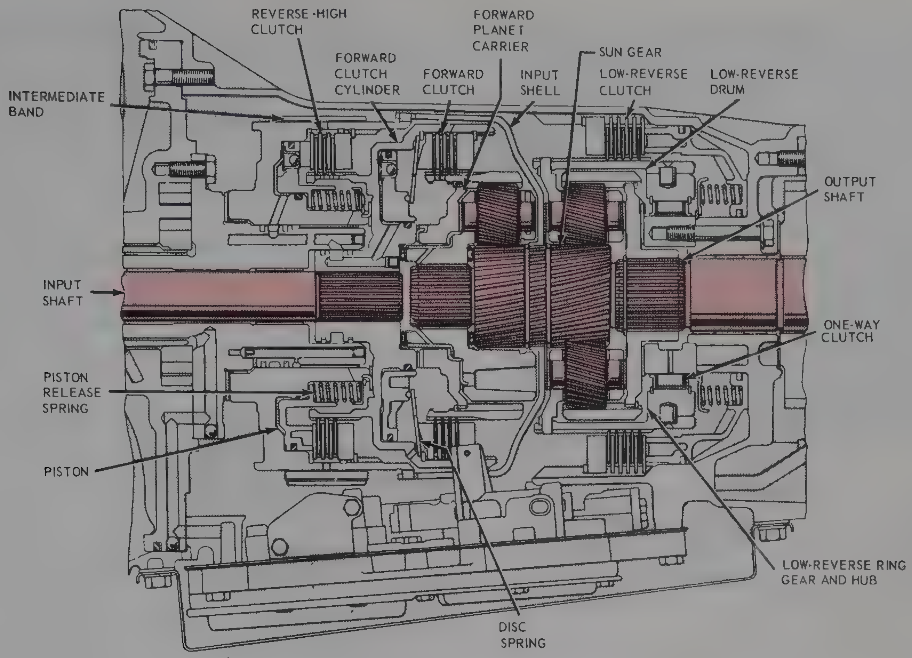

REVERSE-HIGH CLUTCH
FORWARD PLANET CARRIER
FORWARD CLUTCH CYLINDER
FORWARD CLUTCH
INPUT SHELL
SUN GEAR
LOW-REVERSE CLUTCH
LOW-REVERSE DRUM
INTERMEDIATE BAND
OUTPUT SHAFT
INPUT SHAFT
ONE-WAY CLUTCH
PISTON RELEASE SPRING
PISTON
LOW-REVERSE RING GEAR AND HUB
DISC SPRING

Fig. 28-8. Cross-sectional view of unit illustrated in Fig. 28-7. (Ford)

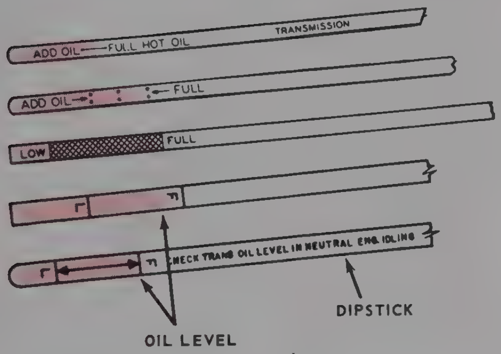

TRANSMISSION
ADD OIL
FULL HOT OIL
ADD OIL
FULL
LOW
FULL
CHECK TRANS OIL LEVEL IN NEUTRAL ENG IDLING
DIPSTICK
OIL LEVEL

Fig. 28-9. Transmission fluid level must be between the ADD and FULL mark on the dipstick. Some of the dipsticks illustrated show a one quart range from add to full, others show one pint. (Standard Oil)

A period of running at fast idle, lever in park or neutral, wheels blocked, and parking brake set, may be used to heat up the fluid.

One manufacturer recommends idling the engine at 750 rpm for two minutes with the transmission in DRIVE as a means of raising the fluid temperature enough for checking.

Use great care when idling a car with the transmission shift lever in any position. Set the brake (disconnect vacuum brake release). Block the wheels. Avoid working under, in front, or in back of the car.

If operating the engine with the transmission in gear, apply both parking and service brakes.

With the car in a level position, fluid temperature normal, engine at idle speed, move the shift lever slowly through the various drive ranges. RETURN lever to either NEUTRAL or PARK as required.

Wipe off the dipstick cap and the end of the fill pipe. Remove dipstick. Wipe it clean. Then insert it back into the fill pipe. Engine must be idling. Make certain dipstick enters to the full depth. Remove dipstick and observe oil level.

Add oil if needed. Under NO circumstances must the level move above the FULL mark. IF the oil level is above full, drain off the required amount.

Unless you are positive that the fluid is HOT, do not add enough fluid to bring the level to the full mark. By keeping the level just under full, when the fluid does reach operating temperature, it will not be overfull.

Never check the oil level with the transmission in any drive range unless specifically recommended by the manufacturer.

Remember: the car must be level, the fluid temperature normal, engine at idle speed, and the shift lever in neutral or park. Look at Fig. 28-10.

INSPECT FLUID

When examining the fluid level on the dipstick, check the oil for discoloration and a foul (burned) smell. Such a condition indicates damaged bands or clutches.

If any water has entered the transmission through the oil cooler, the fluid will have a milky hue. Any appreciable amount will raise the fluid level.

Air bubbles indicate aeration or an air leak in the suction lines.

Factory installed fluid generally contains a red dye (makes finding leaks easier). The fluid in these cases normally has a reddish hue.

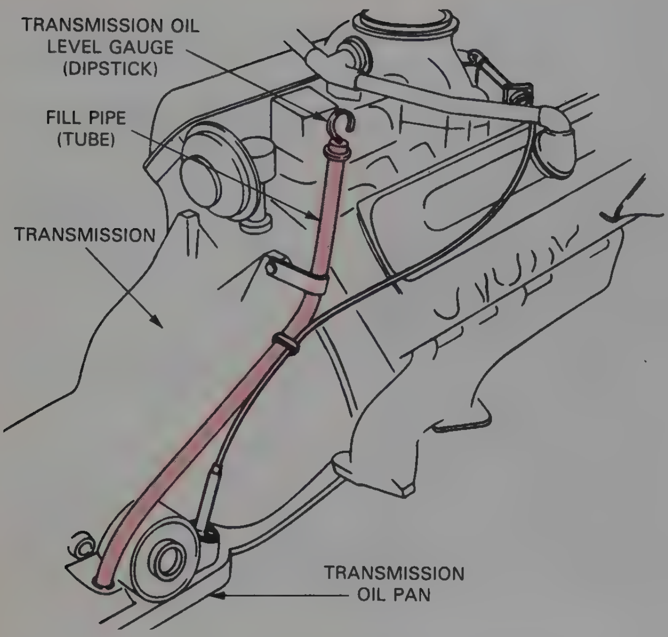

TRANSMISSION OIL LEVEL GAUGE (DIPSTICK)
FILL PIPE (TUBE)
TRANSMISSION
TRANSMISSION OIL PAN

Fig. 28-10. Transmission oil level gauge (stick) and filler pipe (tube). (Chevrolet)

ADD CORRECT FLUID

When adding fluid to any automatic transmission, use only fluids designed specifically for this purpose. The container should be marked with the letters AQ - ATF - (several numbers) - A to indicate that it contains AUTOMATIC TRANSMISSION FLUID, TYPE A, SUFFIX A. Many manufacturers specify special heavy-duty fluid such as DEXRON II. Follow manufacturer's recommendations. Use care when checking the fluid level or adding fluid to prevent dirt from entering the transmission.

TRANSMISSION DRAIN CYCLES

Some car manufacturers recommend periodic transmission draining. Intervals vary from around 12,000 to 100,000 miles (19 300 to 160 000 km), depending upon the type of service.

Some makers do not recommend changing the fluid. Follow the manufacturer's recommendations.

DRAINING TECHNIQUE

The transmission fluid should be at normal operating temperature to insure proper draining.

Some transmissions require draining both the converter and oil pan. Others require draining the oil pan (case) only.

If the pan contains no drain plug, loosen the fasteners to permit draining. If the fill tube attaches to the side of the pan, remove the tube to permit draining. See Fig. 28-11.

Be careful when draining. The fluid may be hot enough to produce serious burns.

Remove the oil pan. Clean the pan and filter screen thoroughly. Replace the filter if recommended. Clean pan and case surfaces. Using a new gasket and cement or RTV silicone, replace the pan, Fig. 28-12. Replace

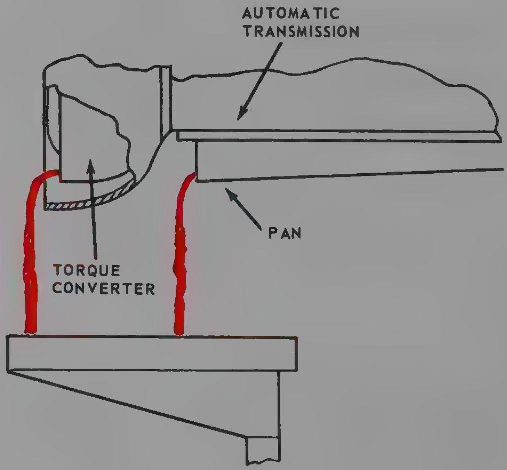

AUTOMATIC TRANSMISSION
PAN
TORQUE CONVERTER

Fig. 28-11. Drain both converter and transmission pan when required.

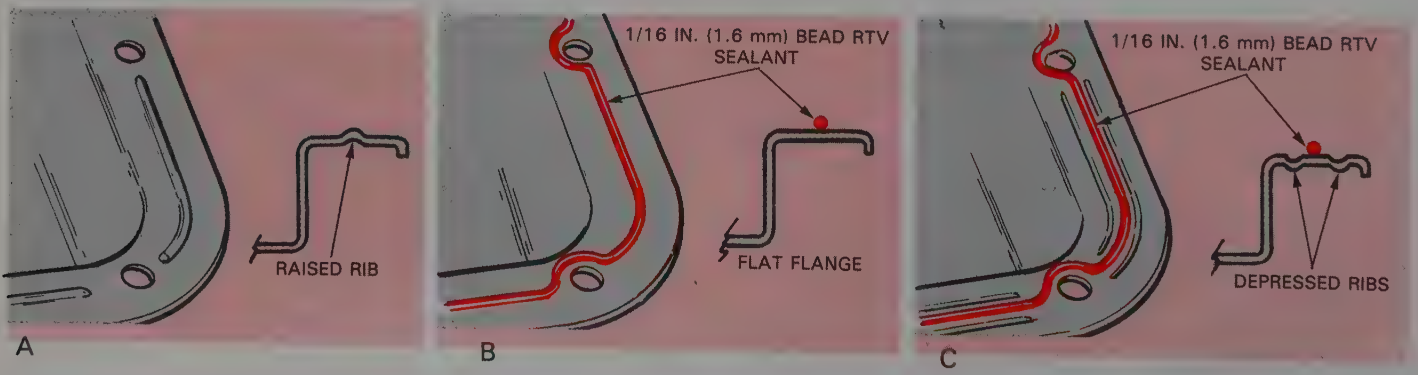

RAISED RIB
1/16 IN. (1.6 mm) BEAD RTV SEALANT
FLAT FLANGE
1/16 IN. (1.6 mm) BEAD RTV SEALANT
DEPRESSED RIBS
A
B
C

Fig. 28-12. Three different transmission oil pan mounting flange designs. A—Raised center rib. It should only be used with a conventional gasket. B—Flat flange. Use RTV sealer or gasket. C—Depressed ribs. Use RTV sealer or gasket. Note positioning of RTV sealer on inside of holes to prevent oil leakage past fasteners. (Chevrolet)

fill pipe if removed, Fig. 28-10.

Install the converter drain plug, where used, and torque as specified. Converter plugs are made of relatively soft material. Do not overtighten.

Some converters require drilling a hole approximately 1/8 in. (3.17 mm) in diameter to facilitate draining. This is shown in Fig. 28-13.

A closed-end (NEVER OPEN END) pop rivet is used to seal the hole. Place a suitable sealer such as Permatex No. 1 on the pop rivet before insertion.

Pressure test converter for leaks using air pressure and liquid soap. Watch for bubbles. If the rivet leaks, the converter MUST be replaced. DO NOT try to drill out defective rivet.

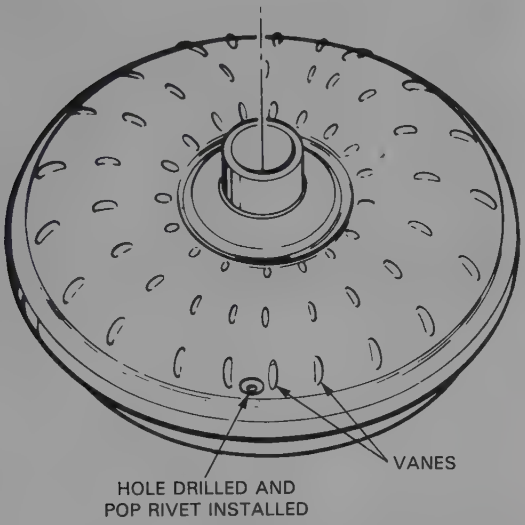


Fig. 28-13. Torque converter with drain hole drilled and pop rivet installed. Always drill between vanes. Coat drill bit with grease to help catch metal chips. Use a closed end rivet coated with approved sealer. (Chevrolet)

TORQUE CONVERTER SERVICE

After converter has been removed and thoroughly drained (about 15 minutes), purge any remaining fluid with air pressure. Put approximately 2 quarts (1.9 litres) of recommended cleaning solvent into converter and shake vigorously. Redrain and use compressed air to blow dry.

Most types of converters (with or without drain plugs) may be pressure cleaned and drained with a special cleaning machine. One is pictured in Fig. 28-14. The converter is bolted to a mounting plate and the proper hoses are connected. The converter is rotated at 20 rpm while cleaning solvent is passed through it. Air is injected into the solvent to aid cleaning action through agitation.

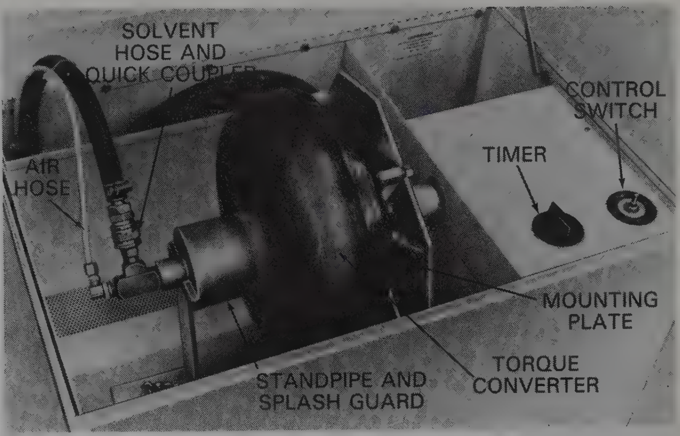


Fig. 28-14. One type of torque converter cleaner. This unit helps remove harmful contaminants (metal particles, sludge, etc.) that can circulate into transmission, plugging filter screens and valve bodies. This unit can also be used for flushing transmission oil coolers. (Owatonna Tool Co.)

After installing converter, transmission, and related parts in vehicle, add the required amount and proper type of new fluid BEFORE starting the engine. Start the engine and move the shift lever through all drive ranges. Then return to park. Idle the car to heat up fluid. Check level when hot. Add more fluid if needed. Check for leaks, Fig. 28-15.

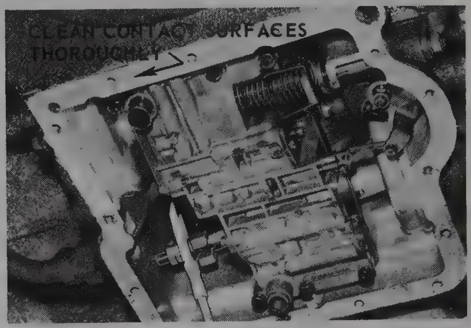


Fig. 28-15. Remove particles of old gasket and gasket cement from both case and oil pan contact surfaces. (Snap-On Tools Corp.)

LEAK DETECTION

When you have to add fluid frequently, it indicates a leak somewhere in the system.

There are a number of potential leak areas such as the extension housing seal, extension housing-to-transmission gasket, oil pan gasket, oil filler-to-pan connection, front seal, converter, drain plugs, shift lever shaft, cooling line connections, and cooler.

At road speed, wind passing the underbody will cause oil to flow back toward the rear of the car. For example, it is quite possible for oil from a leaking rocker arm cover to flow back to the end of the transmission extension housing. At first glance, this might appear to be a leaking rear transmission seal. Other leaking areas can be misleading in the same manner.

ENGINE OIL OR TRANSMISSION FLUID

Do not assume that the fluid dripping from the rear of the transmission or from the converter housing is transmission fluid. It may be engine oil or power steering fluid.

The use of a black light is very helpful in determining the type of fluid. Compare the appearance of the leaking fluid to that on the engine, power steering, and transmission dipsticks.

If needed, a special fluorescent dye may be added to the transmission fluid for positive identification.

Factory installed transmission fluid is generally reddish in color and unless the fluid has been changed, can usually be identified by the color. Refer to Fig. 28-16.

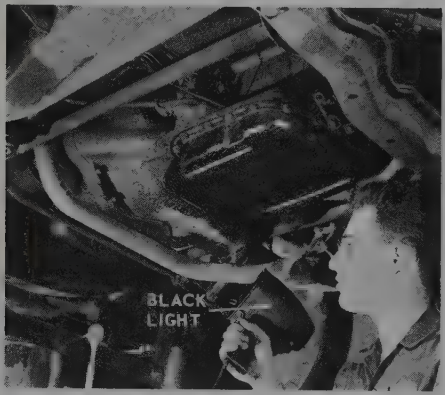


Fig. 28-16. Mechanic using a black light to identify source of oil seepage. (Magnaflux)

REMOVE DIRT AND OIL

It is very difficult to pinpoint the source of a leak when the parts are covered with dirt and oil. Clean the underparts of the engine, converter housing, and transmission. Blow dry with air. Remove the converter housing inspection pan and clean the converter. Clean the inside of the housing. Blow dry.

CHECK FOR LEAKS

Following cleaning, run the engine at fast idle to bring the transmission fluid to normal operating temperature.

Place on a lift. Start engine. Examine for leaks. Shifting the transmission through all drive ranges will help in starting any existing leak. Watch carefully for the first sign of a fluid leak.

If no leaks are apparent, operate the car on the road for several miles, with frequent starts and stops. Place the car on a lift and recheck for leaks.

When fluid flows from the converter housing, it could mean a loose converter drain plug, leaking converter, defective front seal, housing-to-case fastener leak, or similar type problem. Fig. 28-17 illustrates possible leakage points and flow of fluid in a typical converter-housing assembly.

Converter leaks, other than a leaking drain plug, usually require transmission removal.

Pan, speedometer fitting, shift lever shafts, engine rear oil seal, extension housing-to-case, and cooler line fitting leaks usually may be repaired with the transmission in place.

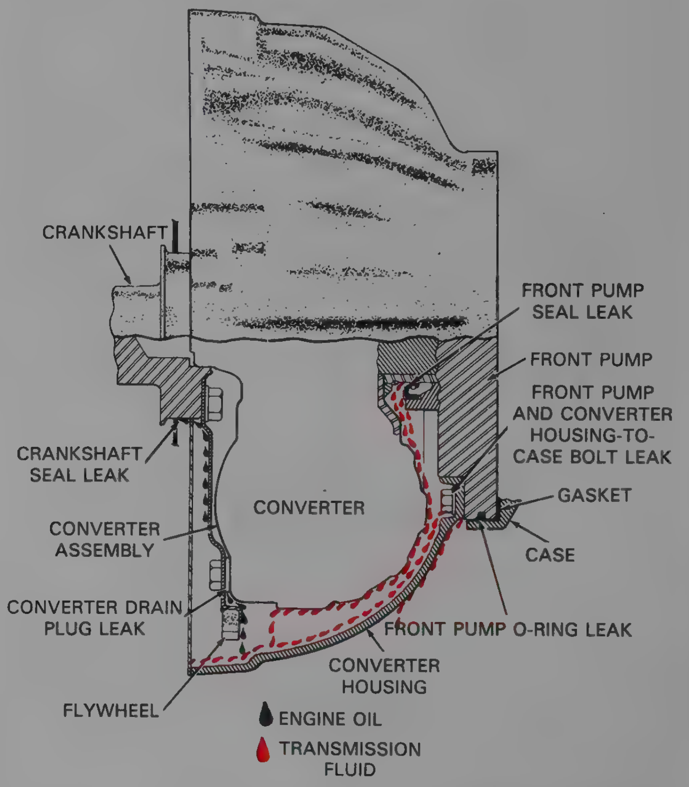


Fig. 28-17. Possible leakage points and flow of fluid in typical converter-housing assembly. (Ford)

REPAIR OF POROUS CASTING

If the leak is the result of a porous casting, a satisfactory repair can often be made by using an epoxy resin.

Operate the car until the transmission reaches FULL OPERATION TEMPERATURE. Clean the case THOROUGHLY AND MARK THE LEAKAGE AREA.

Apply several coats of nonexplosive solvent to the leakage (and surrounding) area. Blow dry after each scrubbing. Immediately following a final scrubbing, apply air until dry.

Mix a batch of epoxy resin (follow directions). Apply a heavy coating to the case. Brush in well. The case should still be hot.

Allow to cure for a minimum of three to four hours before starting car. Following the waiting period, road test and recheck for leaks.

REPLACING REAR SEAL

Drop the propeller shaft (mark to preserve proper alignment). Remove the universal joint yoke from the end of the transmission.

Using a suitable puller, remove the rear seal. A seal, as shown in Fig. 28-18, is easily removed with a hammer.

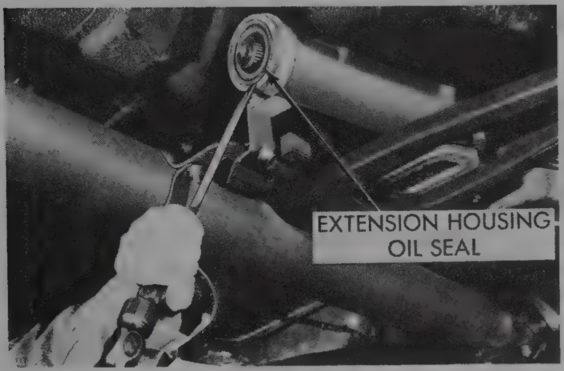


Fig. 28-18. Removing transmission rear seal. (Cadillac)

Clean the seal area of the transmission. Coat the outside of the new seal with sealer. Using a suitable installer, drive the seal into place. The seal lip must face inward toward the transmission.

Wipe the U-joint yoke clean and inspect surface. It must be smooth. Apply a coat of transmission fluid before sliding through the seal, Fig. 28-19.

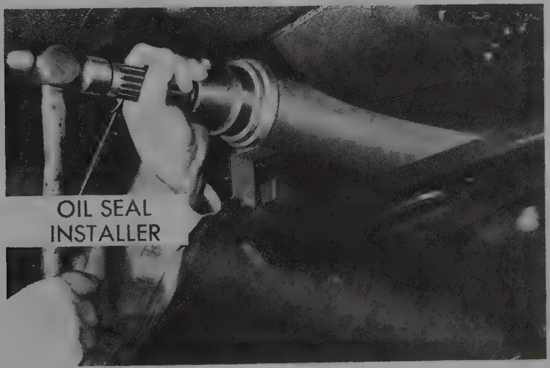


Fig. 28-19. Driving new transmission rear seal into place.

FRONT SEAL REPLACEMENT

Front seal replacement requires transmission removal. See section on removal in this chapter.

Remove the old seal and clean the seal area. Coat the outside of the new seal with nonhardening sealer. Drive seal into place with the lip facing inward. See Fig. 28-20.

When replacing a front oil seal, check for a smooth finish on the converter neck. A worn, rough, or scored finish will prevent the new seal from functioning properly.

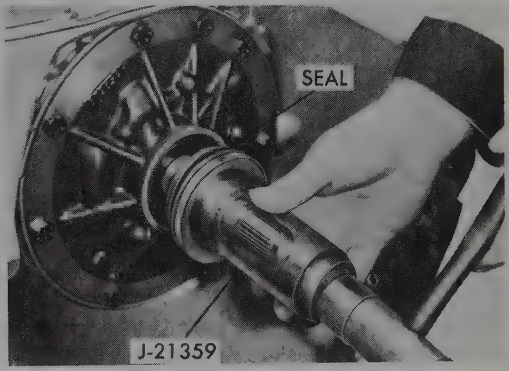


Fig. 28-20. Installing new front seal (transmission removed).

ENGINE CONDITION IS IMPORTANT

It is poor practice to attempt to diagnose transmission problems until the engine has been determined to be in a sound mechanical condition and properly tuned.

The idle speed must be correct. The engine should accelerate from a standing start to any desired speed without coughing or hesitation.

Both engine and transmission must be at operating temperature prior to testing.

TOOLS ARE IMPORTANT

To properly adjust bands, check throttle linkage or make other adjustments, a set of tools designed for the purpose should be available. In addition to the basic set, special purpose items must be acquired to service specific transmissions.

The tool set illustrated in Fig. 28-21 contains most of the basic tools needed for transmission in-car adjustments. A 0-300 psi (0-2 068 kPa) pressure gauge should also be included. Major repair jobs will require many more.

SHIFT LINKAGE ADJUSTMENT

As with the standard or manual transmission, there is a multitude of shift linkage arrangements. Each manufacturer provides specific instructions relating to the year and model concerned.

The object in shift linkage adjustment is to make sure

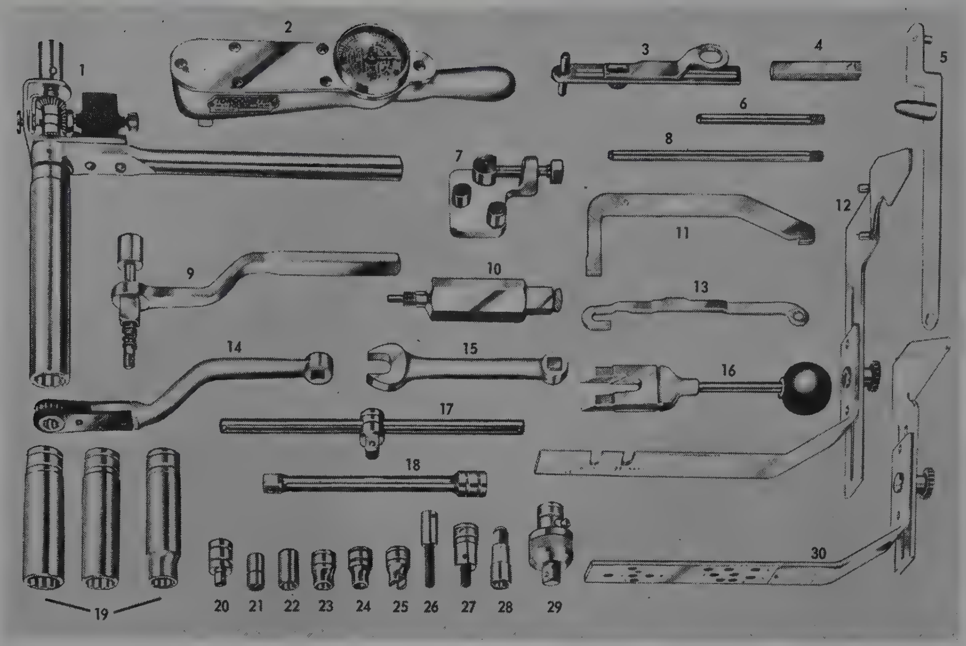


Fig. 28-21. Basic tool set required for automatic transmission in-car adjustments. 1—Band adjusting tool with counter. 2—Torque wrench. 3—Throttle linkage adjustment gauge. 4—.250 in. gauge block. 5—Throttle linkage gauge. 6—Throttle linkage pin. 7—Throttle lever bending tool. 8—Throttle linkage pin. 9—Band adjusting tool. 10—Front Servo gauge. 11—Rear Servo gauge. 12—Throttle lever linkage gauge. 13—Throttle lever linkage gauge. 14—Ratcheting band adjustment adapter. 15—Band adjusting adapter. 16—Rear band gauge. 17—Sliding T bar. 18—Extension bar. 19—Sockets. 20—Adapter. 21—Screwdriver attachment. 22—Double square socket. 23—Square socket. 24—Hex socket. 25—Throttle stop bending tool. 26—Hex bit. 27—Hex bit. 28—Double square socket. 29—Ratchet adapter. 30—Throttle lever gauge. (Snap-On Tools Corp.)

that when the shift lever quadrant indicates a specific drive range, the transmission shift lever is actually in that EXACT position.

Even though the linkage was initially set correctly, wear, loosening of locknuts, and deterioration of engine mounts can alter the setting enough to cause trouble. IF THE ENGINE MOUNTS ARE DAMAGED, DO NOT BOTHER ADJUSTING THE LINKAGE UNTIL NEW MOUNTS ARE INSTALLED. TO DO SO WOULD BE A WASTE OF TIME. THE OLD MOUNTS COULD ALLOW FURTHER SHIFTING OF THE ENGINE AND TRANSMISSION.

The linkage setup pictured in Fig. 28-22 is typical. To adjust this particular model, loosen locknut A until the shift rod slides in the swivel clamp (trunnion) freely.

Move the transmission manual lever into the D1 position (second from rear). Place gearshift selector lever in the D1 position.

When both the transmission manual lever and the gearshift lever are in the D1 positions, tighten the locknut. Move the shift lever through all ranges and check for operation and alignment.

The floor shift in Fig. 28-23 adjusts in much the same way.

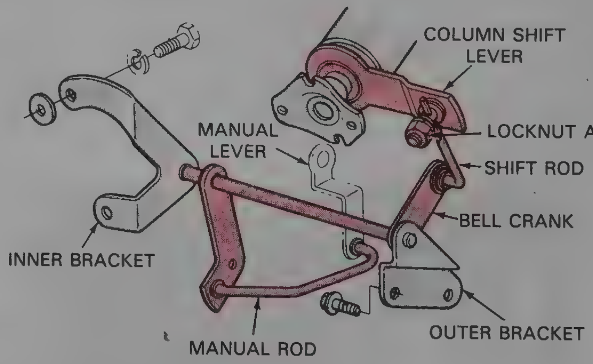


Fig. 28-22. One type of column shift arrangement. (Ford)

Adjust the shift linkage carefully as accuracy is a must. Make certain parking pawl lock functions correctly.

THROTTLE LINKAGE ADJUSTMENT

Throttle linkage adjustment is critical. The relationship between the carburetor throttle opening and the position of the transmission throttle valve, the position of the transmission downshift lever, or the position of

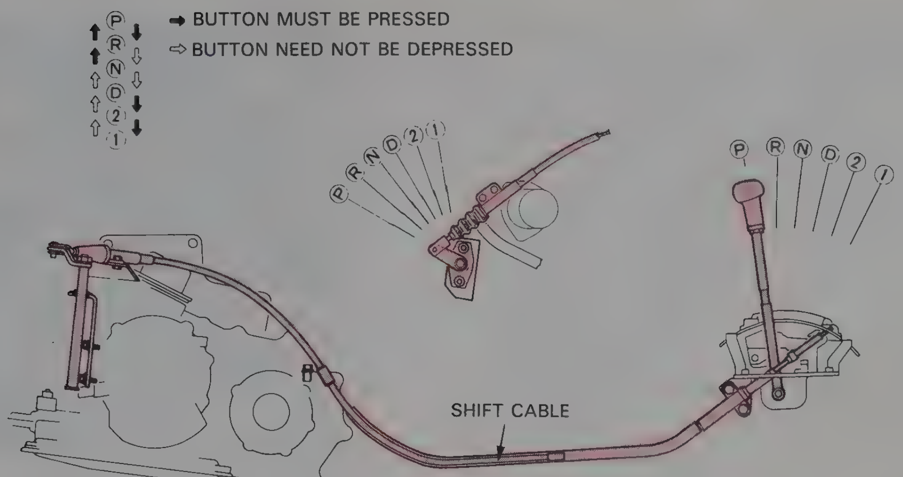

P
R
N
D
2
1
BUTTON MUST BE PRESSED
BUTTON NEED NOT BE DEPRESSED
P R N D 2 1
P R N D 2 1
SHIFT CABLE

Fig. 28-23. One floor shift linkage arrangement with shift cable. (Mazda)

the downshift switch must be as specified by the manufacturer. Faulty adjustment will disturb shift points and can cause ultimate transmission failure.

Any movement of the accelerator pedal must produce a corresponding change in the positioning of the carburetor throttle plates and in the transmission throttle pressure.

TV LINKAGE

Some setups have used a TV (throttle valve) rod connected on one end to the transmission throttle valve lever. The other end connects to the carburetor or throttle body linkage. Any change in throttle plate positioning is reflected in a corresponding change in the transmission lever. Other setups employ a TV cable (wire operating inside of a flexible housing) to produce the same result. Fig. 28-24 illustrates the TV cable arrangement.

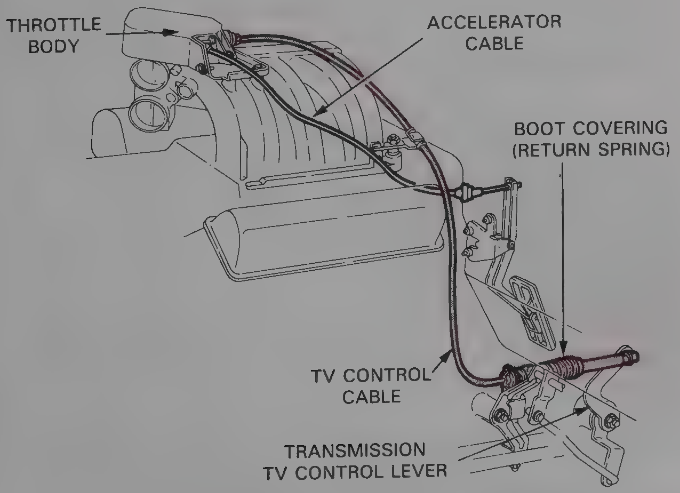

THROTTLE BODY
ACCELERATOR CABLE
BOOT COVERING (RETURN SPRING)
TV CONTROL CABLE
TRANSMISSION TV CONTROL LEVER

Fig. 28-24. Throttle valve (TV) cable attaches to throttle body linkage on one end and to transmission TV lever on other. (Ford)

To adjust TV linkage similar to that in Fig. 28-24, remove the TV rod from the transmission TV lever. Pull the TV lever backward as far as it will move. Using the recommended gauge, as in Fig. 28-25, place gauge in position and check position of TV lever rod opening in relation to the gauge. Bend lever until gauge and lever holes align.

If the TV lever must be bent, use a special bending tool. See Fig. 28-21. Careless bending can cause serious internal damage.

VACUUM CONTROL

Instead of utilizing mechanical linkage (TV rod) to alter shift points in relation to throttle position, many transmissions employ a vacuum diaphragm assembly. This unit is connected to a primary throttle valve or a modulator valve. Engine vacuum operating on the diaphragm alters the positioning of the valve in accordance with engine vacuum (engine load). An additional refinement incorporates an evacuated (air removed) bellows. It provides diaphragm action and adjusts pressure to the valve in accordance with changes in

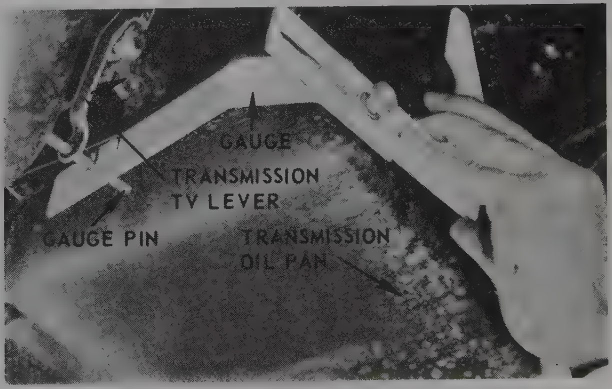

GAUGE
TRANSMISSION TV LEVER
GAUGE PIN
TRANSMISSION OIL PAN

Fig. 28-25. Checking transmission TV lever positioning.

barometric pressure (altitude). Fig. 28-26 illustrates an altitude-compensating vacuum control unit.

When shift points fail to occur as specified, the vacuum control unit should be checked for leakage. This may be accomplished by removing it from the transmission and applying a controlled vacuum to the unit. The vacuum should read the same with the unit attached as with the hose pinched off.

Transmission control pressure can be altered by adjusting the vacuum control, Fig. 28-26. All adjustments must be correlated with engine vacuum and barometric pressure. Some modulators no longer have adjusting screws.

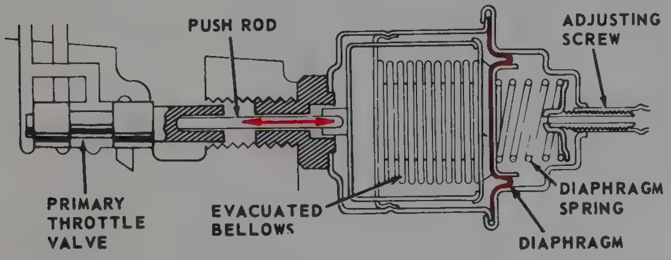

PUSH ROD
ADJUSTING SCREW
PRIMARY THROTTLE VALVE
EVACUATED BELLOWS
DIAPHRAGM SPRING
DIAPHRAGM

Fig. 28-26. Vacuum controlled primary throttle valve. Note use of barometric pressure sensitive bellows. (Ford)

DOWNSHIFT ROD

If the transmission is equipped with mechanical linkage to control forced downshifting, adjust carefully. Downshift rod linkage is pictured in Fig. 28-27.

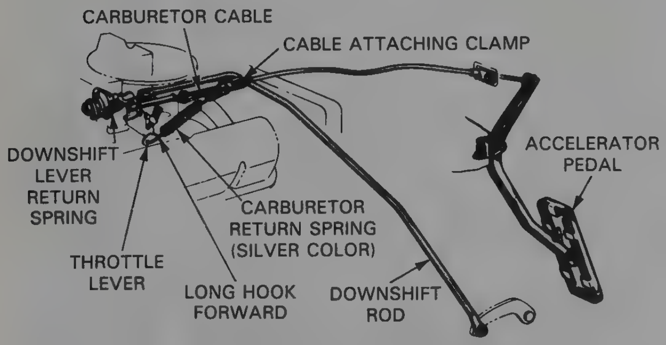

CARBURETOR CABLE
CABLE ATTACHING CLAMP
DOWNSHIFT LEVER RETURN SPRING
ACCELERATOR PEDAL
CARBURETOR RETURN SPRING (SILVER COLOR)
THROTTLE LEVER
LONG HOOK FORWARD
DOWNSHIFT ROD

Fig. 28-27. Downshift rod assembly.

DOWNSHIFT SWITCH

Downshifting at a predetermined throttle valve angle can be accomplished by using a solenoid controlled by a downshift switch.

Where such an arrangement is used, the switch must be properly adjusted. Note the gauge rod and test light to check the adjustment of the downshift switch in Fig. 28-28.

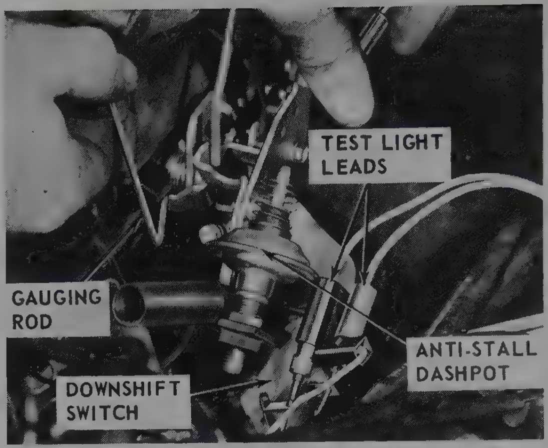

TEST LIGHT LEADS
GAUGING ROD
ANTI-STALL DASHPOT
DOWNSHIFT SWITCH

Fig. 28-28. Checking downshift switch adjustment. (Cadillac)

ACCELERATOR PEDAL HEIGHT AND LINKAGE ACTION

Many throttle linkage adjustment specifications indicate a definite distance between the bottom of the accelerator pedal and the floor mat. With this measurement as specified, the engine hot idle speed must be correct as well as the adjustment of the TV control rod where used or the downshift rod.

When the accelerator is fully depressed, the carburetor throttle valves must be in the wide open position. The linkage action must be smooth and free of binding. Lubricate as needed.

ANTI-STALL THROTTLE RETURN DASHPOT

The throttle return dashpot must be adjusted to prevent stalling when the accelerator pedal is suddenly released. Refer to the chapter on FUEL SYSTEM SERVICE-CARBURETORS for details. Note throttle return dashpot in Fig. 28-28.

NEUTRAL SAFETY SWITCH

Always check the neutral safety starting switch for proper operation. The engine should crank with the selector lever in either the NEUTRAL or PARK position. The engine should not crank with the selector lever in any other position.

Adjust or replace the safety switch as needed.

The switch may be located on the steering column, on the floor shift console, or on the transmission itself. Refer to Fig. 28-29.

STALL TESTING

The stall test is used on some transmissions to determine the condition of the disc clutches, bands, one-way clutch, and other parts.

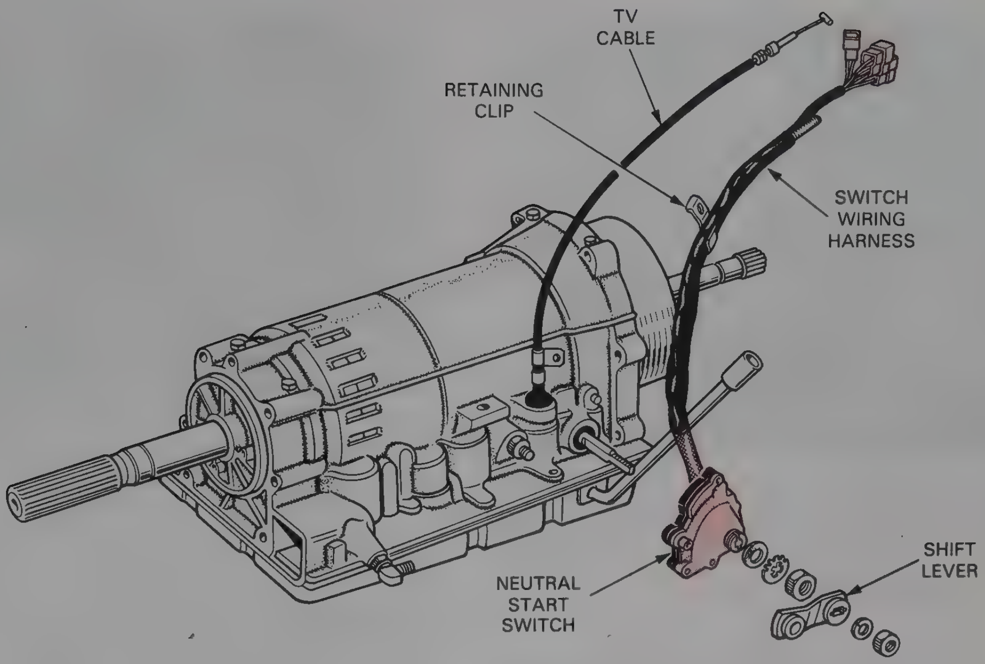


Fig. 28-29. One type of neutral safety start switch and wiring harness. (Toyota)

SOME TRANSMISSIONS MUST NOT BE STALL TESTED. FOLLOW MANUFACTURER'S INSTRUCTIONS.

To stall test a transmission, bring the engine to normal operating temperature. Connect a tachometer so that it may be read from the driver's seat. Apply BOTH the parking and service brakes. Place the selector lever in the recommended stall test position (D1, D2, R, etc.). While holding the brakes on with great force, push the throttle to the RECOMMENDED THROTTLE position. DO NOT GO BEYOND FULL THROTTLE INTO THE KICKDOWN POSITION UNLESS SO RECOMMENDED.

Note the rpm indicated while operating at full throttle. If engine speed is below specifications, it can indicate engine or converter stator problems. Rpm above that specified can mean slipping bands or clutches.

When stall testing, never keep the accelerator pedal in the full throttle position for longer than five seconds. To do so will seriously overheat the transmission. Return the selector lever to the neutral position and operate the engine at around 1200 rpm for a minute or two before stall testing a different drive range.

When stall testing, if the engine rpm exceeds stall specifications, release the accelerator immediately.

Make certain the brakes are firmly applied and keep people out of the way.

PRESSURE CHECKS

Oil pressures, check points, and methods of checking vary. Follow manufacturer's directions.

Always bring the transmission to full operating temperature before running pressure checks. Check fluid level.

Clean foreign material away from check plug. Remove plug and connect a suitable pressure gauge. Gauge hose should be long enough to reach the driver's compartment for road testing. A typical gauge, 0-300 psi (0-2 068 kPa) is shown connected to the check point in Fig. 28-30. Note long hose.

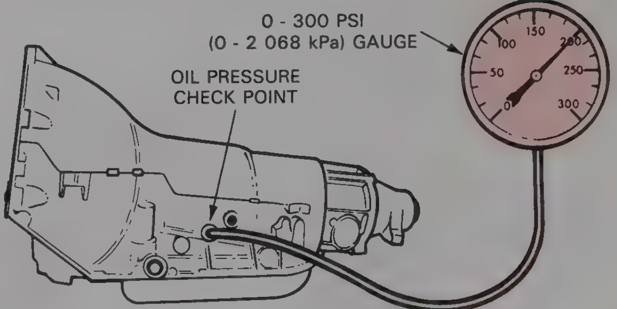


Fig. 28-30. Test gauge connected for transmission oil pressure check. (Jeep)

If needed, attach a tachometer to provide accurate rpm check points, Fig. 28-31. Drive the car at the recommended road speeds. Check the pressure in the specified drive range.

Other tests are performed in the shop. Be careful to place in the correct range and operate at the exact rpm. Compare gauge readings with those specified.

A vacuum gauge (in addition to a pressure gauge and

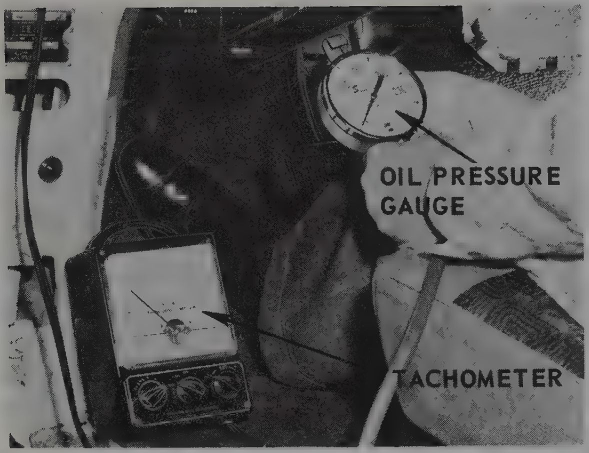


Fig. 28-31. By placing both tachometer and pressure gauge in driver's compartment, engine rpm and transmission oil pressure can be readily observed during road testing. (Snap-On Tools Corp.)

tachometer) is required to check control oil pressure in applications using a vacuum control unit.

The vacuum modulator test setup shown in Fig. 28-32 uses a hand held vacuum pump in place of engine vacuum.

Manufacturers provide specifications showing the correct control pressure at a given engine vacuum. If an altitude-compensating vacuum unit is used, be sure to make allowance for the barometric pressure during the test.

Barometric pressure will lower about 1 in. Hg for every 1,000 feet (305 meters) rise in elevation. Barometric pressure can also vary MORE than 1 in. Hg at any given elevation, depending upon weather conditions.

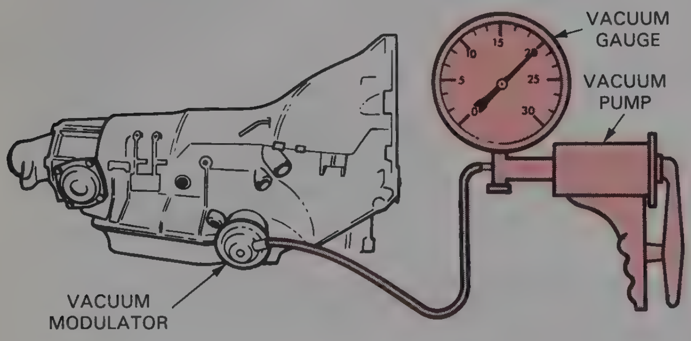


Fig. 28-32. Vacuum gauge and pump combination being used to check vacuum modulator. (Chevrolet)

SHIFT POINT CHECK

Bring transmission to the normal operating temperature. Move the selector lever from neutral through all drive ranges (engine at normal idle rpm). These initial clutch and band engagements should be smooth. Harsh engagements can indicate either excessive engine idle rpm or control pressures.

Road test the car. From a standing start, normal acceleration, the transmission should shift from first to second and second to third (three speed transmission). Engagement at each shift should be smooth yet positive with no sign of slippage.

Accelerate from a standstill several times using only enough throttle (minimum throttle test) to cause the transmission to upshift. Check against recommended upshift points. Try the maximum throttle upshift points. Try the forced downshift by depressing the throttle (transmission in third or high gear) all the way to the floor.

Check closed throttle downshift by releasing the accelerator pedal at about 35 mph (56 kph) and allowing the car to coast down.

Specified shift points (road speed or engine rpm at which transmission shifts) depend upon such things as engine size, tire size, and rear axle ratios.

If the transmission has a lockout feature for first gear (car starts in second to provide better traction for slippery roads), place the selector in the lockout (D2, etc.) range. Car should start out in second gear.

Try all drive ranges to see that the transmission shifts into the proper gears for the specific range.

BAND ADJUSTMENT

Some transmissions require periodic band adjustments to compensate for normal wear. Other designs, in which the band is subjected to moderate wear, do not require adjustment at periodic intervals.

WHEN YOU ARE MAKING BAND ADJUSTMENTS, MAKE CERTAIN THE SPECIFICATIONS RELATE TO THE TRANSMISSION AT HAND. FOLLOW SPECIFICATIONS EXACTLY. FAILURE TO DO SO MAY CAUSE SERIOUS TRANSMISSION DAMAGE.

Some external band adjustments are reached through the floor pan after turning the mat to one side, Fig. 28-33. Others are accessible from beneath the car, Fig. 28-34. A few require removal of the transmission oil pan, Fig. 28-35.

The typical external adjustment consists of an adjusting screw passing through the case and engaging one end of the band. A locking nut is provided to secure the adjusting screw. Fig. 28-36 illustrates a band, servo, and adjustment arrangement.

General adjusting procedure requires loosening the locknut several turns, tightening the adjustment screw to an EXACT TORQUE and then backing the screw off an EXACT NUMBER OF TURNS. The screw is held in this position while the locknut is tightened. Remember: this is a critical adjustment and must be done exactly as specified.

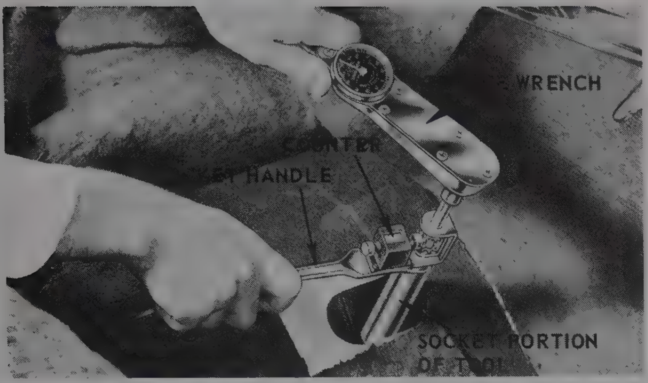

WRENCH
COUNTER
HANDLE
SOCKET PORTION OF TOOL

Fig. 28-33. Adjusting band through floor pan. Note counter device to keep track of exact number of turns adjusting screw is loosened following torquing. (Snap-On Tools Corp.)

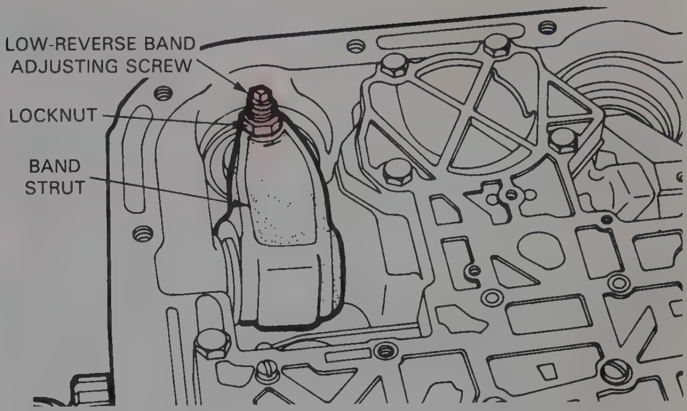

LOW-REVERSE BAND ADJUSTING SCREW
LOCKNUT
BAND STRUT

Fig. 28-35. This transmission requires the removal of oil pan to adjust low-reverse band. (Chrysler)

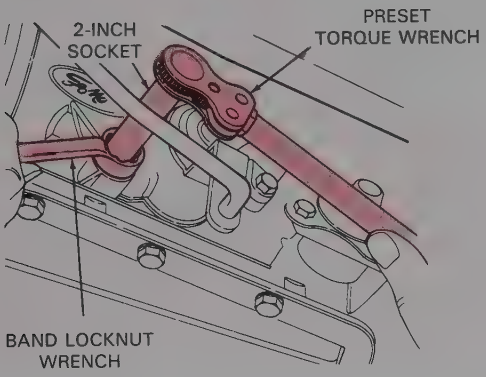

2-INCH SOCKET
PRESET TORQUE WRENCH
BAND LOCKNUT WRENCH

Fig. 28-34. Tightening band adjusting screw from under the vehicle with preset torque wrench.

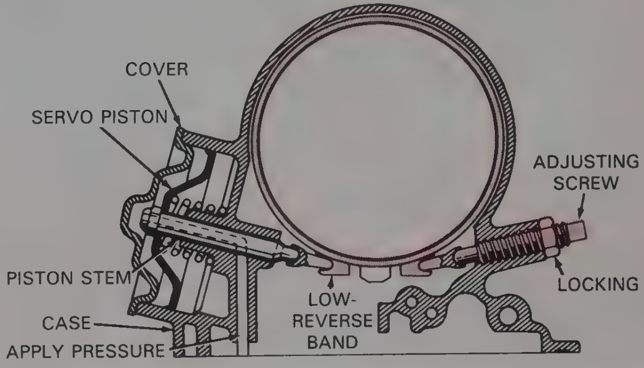

COVER
SERVO PISTON
ADJUSTING SCREW
PISTON STEM
LOCKING NUT
LOW-REVERSE BAND
CASE
APPLY PRESSURE

Fig. 28-36. Typical band adjustment device.

In Fig. 28-34, a mechanic is using a special wrench to tighten the adjusting screw. When the correct torque is reached, the wrench will click and overrun. This wrench (preset torque wrench) must be used only on transmissions for which it was designed.

In using the tool shown in Fig. 28-33, the locknut is loosened with the socket and the adjusting screw is brought to recommended torque with a regular torque wrench. The dial counter is then set to zero. As the adjusting screw is backed out, the counter will record the exact number of turns. When the correct number is reached, the adjustment screw is held stationary and the locknut is tightened.

When band adjustments are difficult to reach, an extension, such as the one pictured in Fig. 28-37, is helpful. Remember that when an extension is used with the torque wrench, indicated torque (dial reading) is less than actual torque. See chapter on fasteners and torque wrench.

The transmission shown in Fig. 28-35 requires removal of the oil pan to make one of the band adjustments.

Following band adjustment, road test the car for proper shift operation.

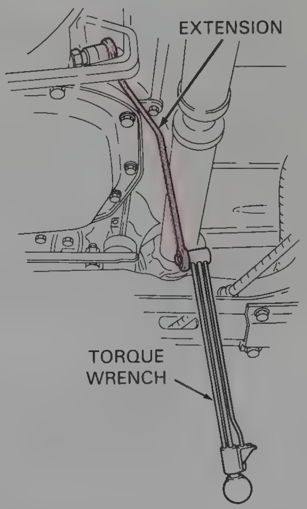

EXTENSION
TORQUE WRENCH

Fig. 28-37. An extension makes this adjustment screw easy to torque. (Jeep)

REMOVAL OF EXTENSION HOUSING AND BUSHING

Drop the drive line. Remove U-joint yoke or flange. Disconnect speedometer cable. Remove speedometer

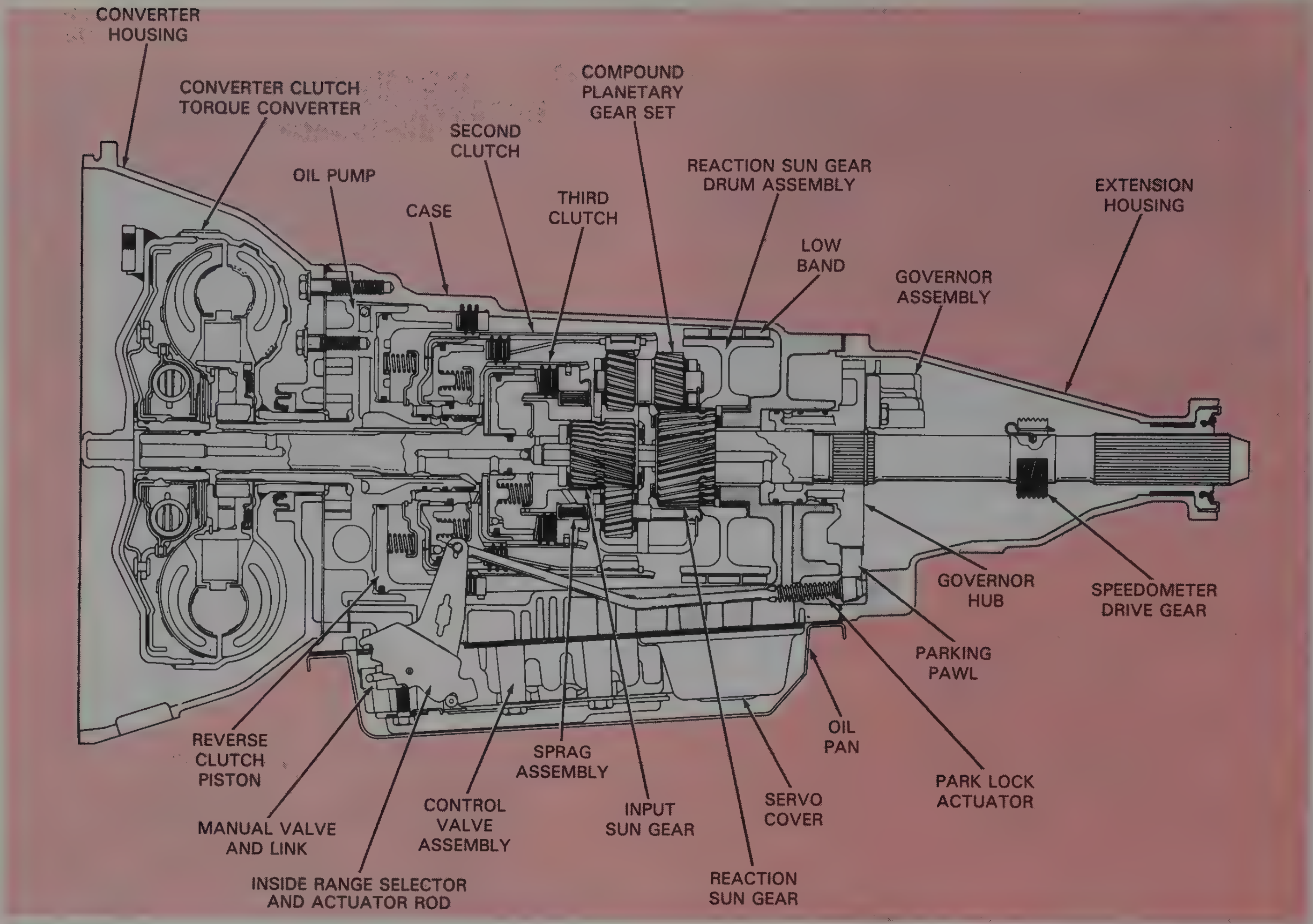

CONVERTER HOUSING
CONVERTER CLUTCH TORQUE CONVERTER
OIL PUMP
CASE
SECOND CLUTCH
THIRD CLUTCH
COMPOUND PLANETARY GEAR SET
REACTION SUN GEAR DRUM ASSEMBLY
LOW BAND
GOVERNOR ASSEMBLY
EXTENSION HOUSING
GOVERNOR HUB
SPEEDOMETER DRIVE GEAR
PARKING PAWL
OIL PAN
PARK LOCK ACTUATOR
SERVO COVER
REACTION SUN GEAR
INPUT SUN GEAR
SPRAG ASSEMBLY
CONTROL VALVE ASSEMBLY
INSIDE RANGE SELECTOR AND ACTUATOR ROD
MANUAL VALVE AND LINK
REVERSE CLUTCH PISTON

Fig. 28-38. Cross-sectional view of a three speed automatic transmission. This unit uses a compound planetary gearset and lock-up torque converter. Note extension housing. (Chevrolet)

drive assembly. Remove any other required unit. Drain the required amount of oil.

Remove the crossmember-to-extension housing bolts. Raise the transmission and remove the crossmember.

Remove the extension housing-to-transmission fasteners and slide the housing off. Fig. 28-38 illustrates a typical housing setup.

Fig. 28-39 illustrates the removal and installation of an extension housing bushing after housing removal.

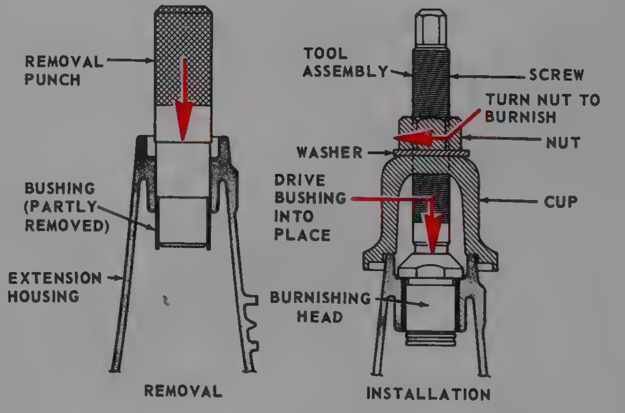

REMOVAL PUNCH
BUSHING (PARTLY REMOVED)
EXTENSION HOUSING
REMOVAL
TOOL ASSEMBLY
SCREW
TURN NUT TO BURNISH
NUT
WASHER
DRIVE BUSHING INTO PLACE
CUP
BURNISHING HEAD
INSTALLATION

Fig. 28-39. Removing extension housing bushing with removal punch. The new bushing is driven in until seated. The screw is then held stationary and the nut is turned to draw burnishing head through bushing. (Plymouth)

GOVERNOR

The removal of the extension housing has exposed the governor on the transmission illustrated in Fig. 28-40. Necessary work on the governor may be performed at this time.

Governors on some other transmissions are accessible by removing a cover plate. Removal of the extension housing, in these cases, is not necessary.

CONTROL VALVE BODY

The control valve body assembly is removed by draining the oil, pulling the pan, and removing the valve body-to-transmission fasteners. When removing the valve body, be sure to release slowly and catch any springs or parts that may fall free. Do not use gasket cement when replacing valve body. An exploded view of a typical valve body is shown in Fig. 28-41.

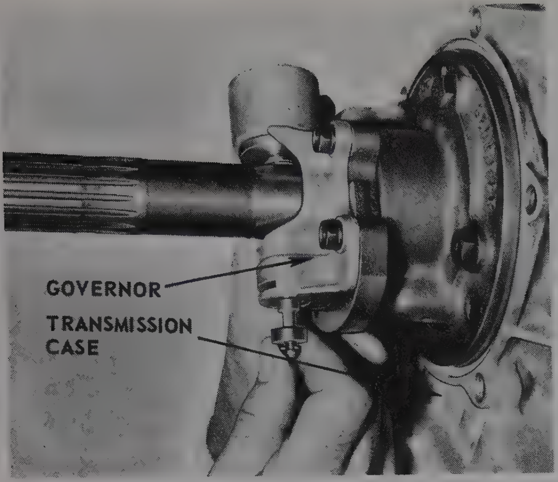

GOVERNOR
TRANSMISSION CASE

Fig. 28-40. Removal of extension housing on this transmission, has exposed governor for repair work. (G.M.C.)

CHECKING CLUTCH AND BAND ACTION WITH AIR PRESSURE

The removal of the control valve body makes it possible to apply air pressure as a means of checking clutch and band operation on some transmissions. The transmission in Fig. 28-42 has had the control valve body removed. Note the case oil passageways.

The front clutch action is being checked in Figs. 28-43 and 28-44. When air is applied, a distinct thump can be heard or felt if the clutch piston is functioning.

The application of air to the band servo apply passageways will cause the band to tighten. Application to the servo release passage will cause the band to loosen. USE CLEAN, DRY AIR ONLY. NOZZLE

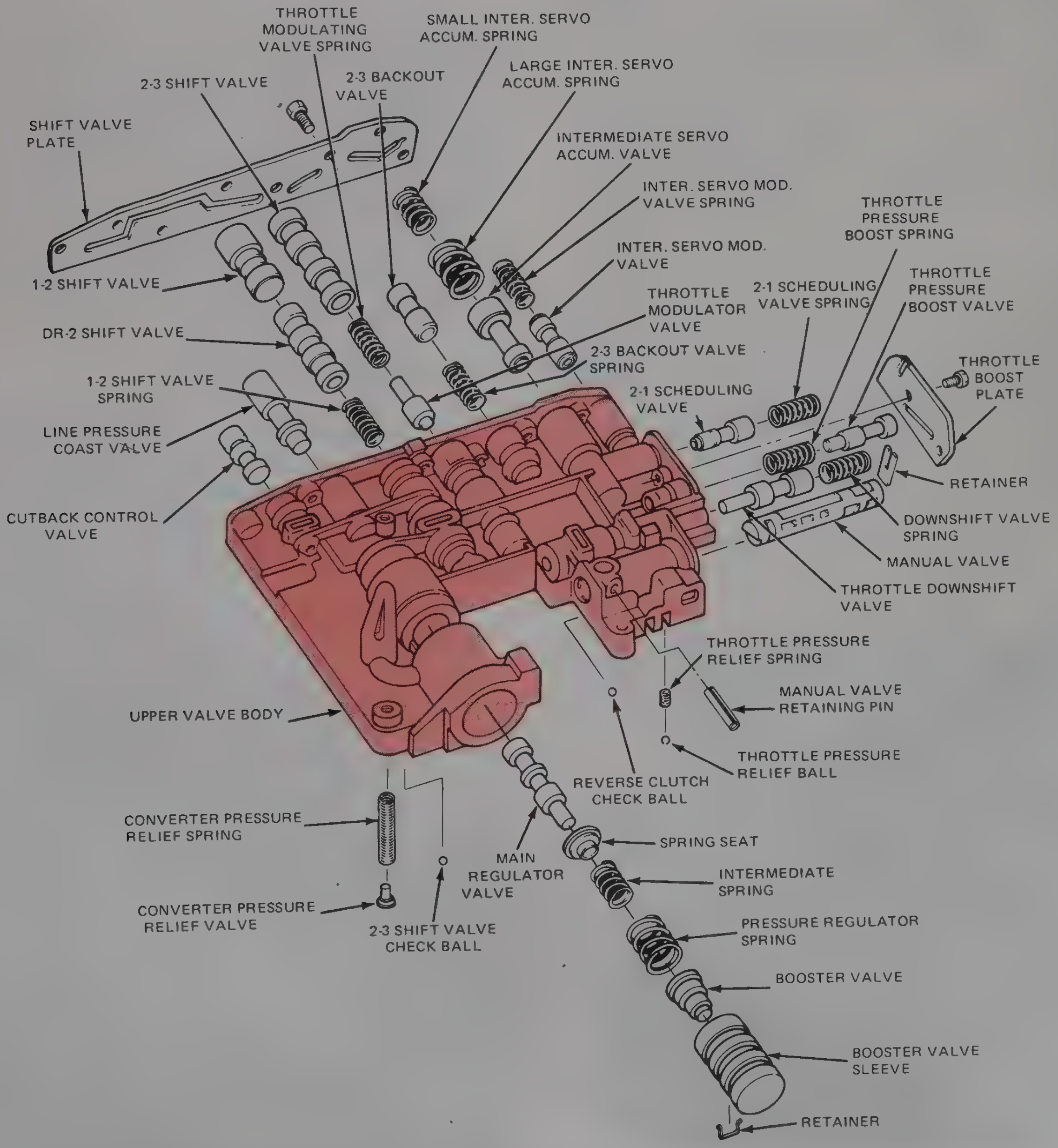

THROTTLE MODULATING VALVE SPRING
SMALL INTER. SERVO ACCUM. SPRING
LARGE INTER. SERVO ACCUM. SPRING
2-3 SHIFT VALVE
2-3 BACKOUT VALVE
SHIFT VALVE PLATE
INTERMEDIATE SERVO ACCUM. VALVE
INTER. SERVO MOD. VALVE SPRING
THROTTLE PRESSURE BOOST SPRING
INTER. SERVO MOD. VALVE
THROTTLE PRESSURE BOOST VALVE
1-2 SHIFT VALVE
THROTTLE MODULATOR VALVE
2-1 SCHEDULING VALVE SPRING
DR-2 SHIFT VALVE
THROTTLE BOOST PLATE
2-3 BACKOUT VALVE SPRING
1-2 SHIFT VALVE SPRING
2-1 SCHEDULING VALVE
LINE PRESSURE COAST VALVE
RETAINER
CUTBACK CONTROL VALVE
DOWNSHIFT VALVE SPRING
MANUAL VALVE
THROTTLE DOWNSHIFT VALVE
THROTTLE PRESSURE RELIEF SPRING
UPPER VALVE BODY
MANUAL VALVE RETAINING PIN
THROTTLE PRESSURE RELIEF BALL
REVERSE CLUTCH CHECK BALL
CONVERTER PRESSURE RELIEF SPRING
SPRING SEAT
MAIN REGULATOR VALVE
INTERMEDIATE SPRING
CONVERTER PRESSURE RELIEF VALVE
2-3 SHIFT VALVE CHECK BALL
PRESSURE REGULATOR SPRING
BOOSTER VALVE
BOOSTER VALVE SLEEVE
RETAINER

Fig. 28-41. Exploded view of one type of valve body. This unit is used with a three speed automatic. (Ford)

MUST BE CLEAN. BE SURE TO USE AIR ON CORRECT PASSAGEWAYS AND DO NOT EXCEED MANUFACTURER'S RECOMMENDED MAXIMUM TESTING AIR PRESSURES.

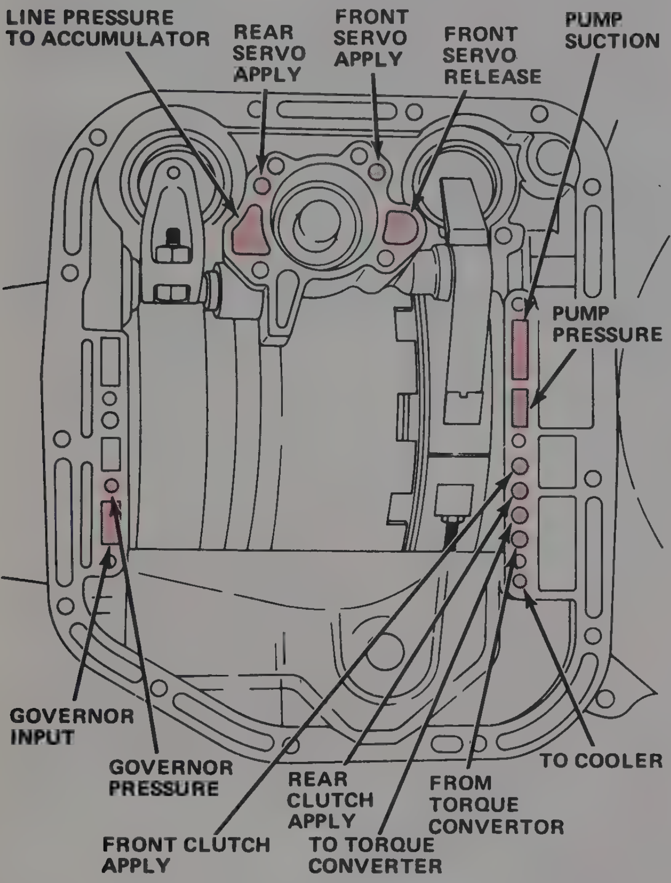

LINE PRESSURE TO ACCUMULATOR
REAR SERVO APPLY
FRONT SERVO APPLY
FRONT SERVO RELEASE
PUMP SUCTION
PUMP PRESSURE
GOVERNOR INPUT
GOVERNOR PRESSURE
REAR CLUTCH APPLY
FROM TORQUE CONVERTOR
TO COOLER
FRONT CLUTCH APPLY
TO TORQUE CONVERTER

Fig. 28-42. Case oil passages have been exposed by removing oil pan and valve body. (Jeep)

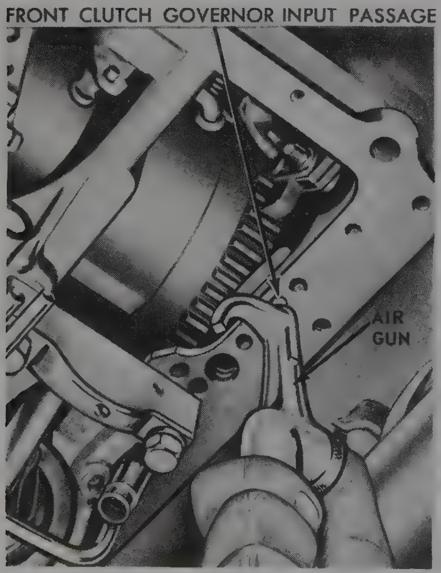

FRONT CLUTCH GOVERNOR INPUT PASSAGE
AIR GUN

Fig. 28-43. Applying air pressure to check clutch action.

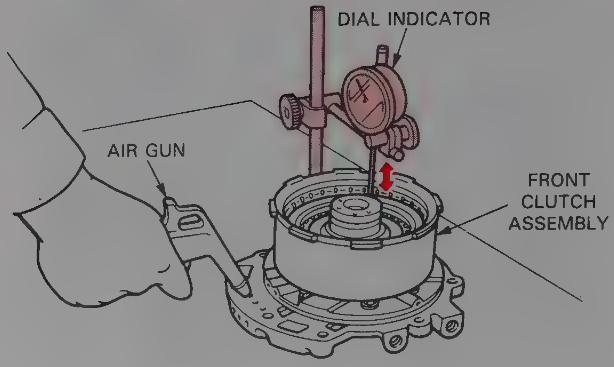

DIAL INDICATOR
AIR GUN
FRONT CLUTCH ASSEMBLY

Fig. 28-44. Front clutch unit being checked with air gun. This particular clutch has been removed from transmission for checking. Note dial indicator being used to measure clutch clearance (travel). (Mazda)

OTHER IN-CAR CHECKS AND REPAIRS

Depending upon transmission design, a number of other tests and repairs can often be performed with the transmission in the car.

The vacuum modulator, modulator valve, servo, and park lock device can often be removed, inspected, and replaced without pulling the transmission. Follow manufacturer's recommendations.

TRANSMISSION REMOVAL

To begin transmission removal, disconnect the battery ground strap. Remove starter unless needed to rotate drive plate to remove converter-to-drive plate fasteners. Remove wires, coolant lines, shift rod, vacuum line, downshift rod, filler tube, speedometer cable, and other parts.

Mark and remove the propeller shaft. Drain the transmission and the converter where possible.

Drop the converter housing pan and remove the converter-to-drive plate (flywheel) fasteners. Mark the converter and drive plate to assure proper assembly. NEVER USE A PRY BAR OR SCREWDRIVER TO ROTATE THE DRIVE PLATE BY PRYING ON THE RING GEAR TEETH. TO DO SO CAN SPRING THE DRIVE PLATE. Some makers recommend prying on the converter weld nuts, Fig. 28-45. The starter, if left in place, may be used.

Place a jack under the engine. DO NOT DAMAGE THE PAN. If needed, raise the engine-transmission assembly (after removing transmission support-to-crossmember fasteners). Remove the crossmember.

Position a transmission jack under the transmission. ALWAYS SECURE THE TRANSMISSION TO THE JACK WITH A SAFETY CHAIN.

Remove the converter housing-to-engine fasteners. Make sure the engine is supported. Work the transmission AND CONVERTER back far enough to position

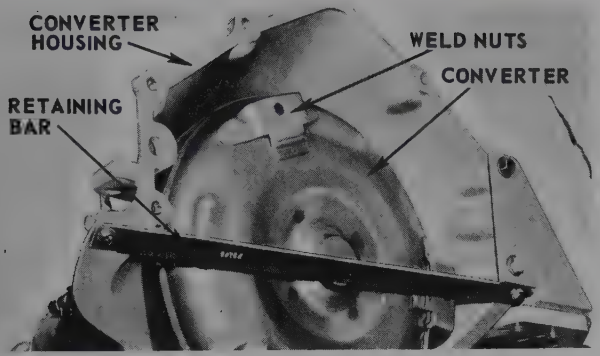

CONVERTER HOUSING
WELD NUTS
CONVERTER
RETAINING BAR

Fig. 28-45. Always use retaining bar or strap to prevent converter from falling off during transmission removal or installation. (G.M.C.)

a converter retaining clamp or bar. The transmission and converter are removed as an assembly. The retaining bar will prevent the converter from dropping off during removal. See Fig. 28-45.

Pull the transmission back until clear and then lower. Never during removal or installation must the weight of the transmission or converter rest on the drive plate. Look at Fig. 28-46.

Fig. 28-47 illustrates a transmission and rear support crossmember assembly.

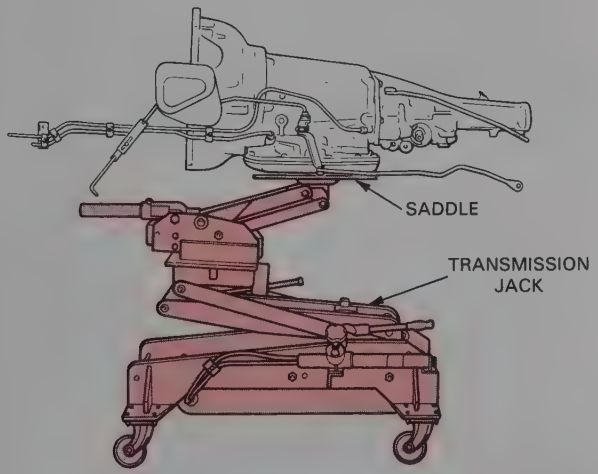

SADDLE
TRANSMISSION JACK

Fig. 28-46. One type of transmission jack. Before removing transmission, use a safety chain or bolted bracket to secure transmission to jack saddle! (Chrysler)

FLUSHING OIL COOLER

To avoid the possibility of damage to a new or rebuilt transmission, the oil cooler and lines should be thoroughly flushed to remove any metal particles or other material.

Use clean solvent or kerosene and a pressure gun. Reverse flush until the solvent comes out clean. Do not use pressure in excess of recommended amount.

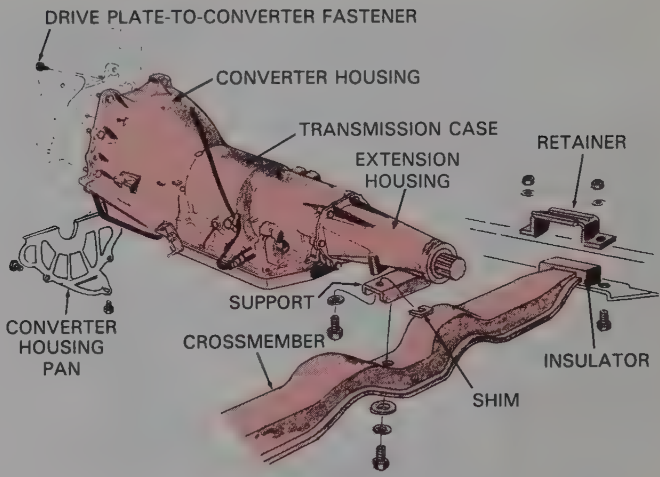

DRIVE PLATE-TO-CONVERTER FASTENER
CONVERTER HOUSING
TRANSMISSION CASE
RETAINER
EXTENSION HOUSING
SUPPORT
CONVERTER HOUSING PAN
CROSSMEMBER
INSULATOR
SHIM

Fig. 28-47. Transmission and support crossmember assembly. (Oldsmobile)

Flush out the solvent (in normal direction of flow) with automatic transmission fluid. Pass fluid through the lines until all the solvent is removed. Cap the lines until ready to connect.

Flushing may also be done by installing the transmission and filling with the recommended amount of fluid. connect the transmission oil outlet line only. Place the inlet end in a container. Start the engine, move the gear selector through the various ranges and return to NEUTRAL. Allow about one quart of fluid to pump through the lines. Stop the engine and add another quart of fluid. Continue this process until the fluid coming out the return pipe is clear and clean. Connect line.

The first method, using a reverse flushing technique, is usually preferred.

A flushing unit, such as that pictured in Fig. 28-14, does a fine job of flushing the cooler. Follow manufacturer's recommendations for correct procedure.

Note the wrench being used to tighten the oil cooler line connections in Fig. 28-48.

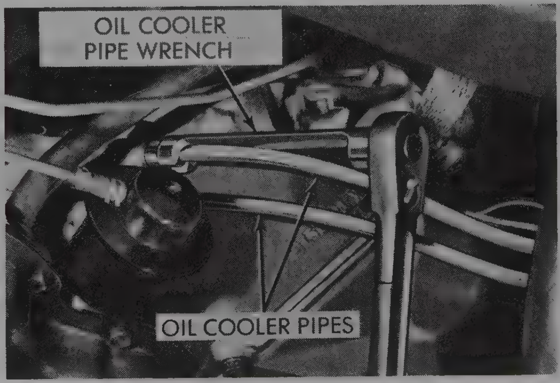

OIL COOLER PIPE WRENCH
OIL COOLER PIPES

Fig. 28-48. Following flushing, connect oil cooler lines. (Cadillac)

If the oil flow through the lines seems impeded, check for dents or a pinched section. Replace line if damaged. Be extremely careful with plastic cooler lines and the connectors. Keep away from sharp or hot areas. Replace radiator if the cooler is clogged and cannot be cleaned. Fig. 28-49 shows two typical cooler line arrangements.

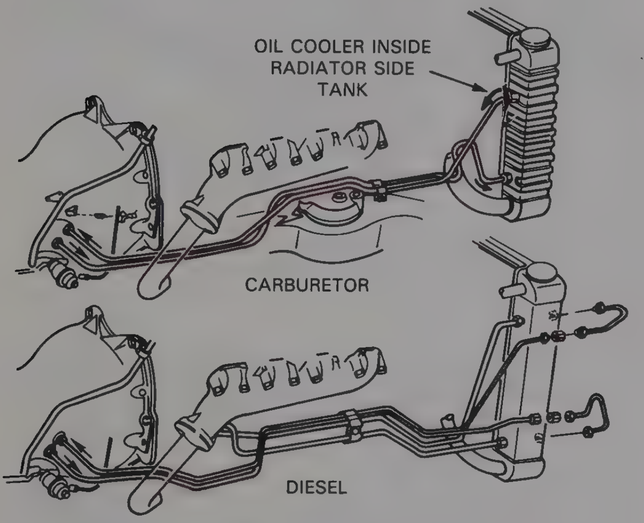


Fig. 28-49. Typical transmission oil cooler line arrangements for a carbureted (gasoline) and for a diesel engine. (Buick)

Fig. 28-50 illustrates an auxiliary transmission cooler. These are used to increase the standard units cooling capacity on transmissions that are operated under severe conditions; trailer towing and snow plow usage, for example. They are generally located in front of the radiator.

TRANSMISSION INSTALLATION

Install the transmission in the reverse order of removal. Keep the following points in mind:

Install transmission and torque converter as an assembly. Make sure the converter is mounted to the transmission properly and to the full depth. See Fig. 28-51. Use a retaining strap. Align converter and drive plate marks. converter must approach the drive plate squarely. Be certain the converter hub or pilot enters the recess in the crankshaft. Do not allow the weight of the transmission to hang on the drive plate. Torque fasteners. Avoid prying on the drive plate.

When completely installed and all lines, wires, linkage, and other parts are connected, add the prescribed amount of fluid. Start the engine. Move the selector through the gears. Check level and add more fluid if required. Bring to normal operating temperature. Check for leaks. Road test. Make final adjustments and another check for leakage.

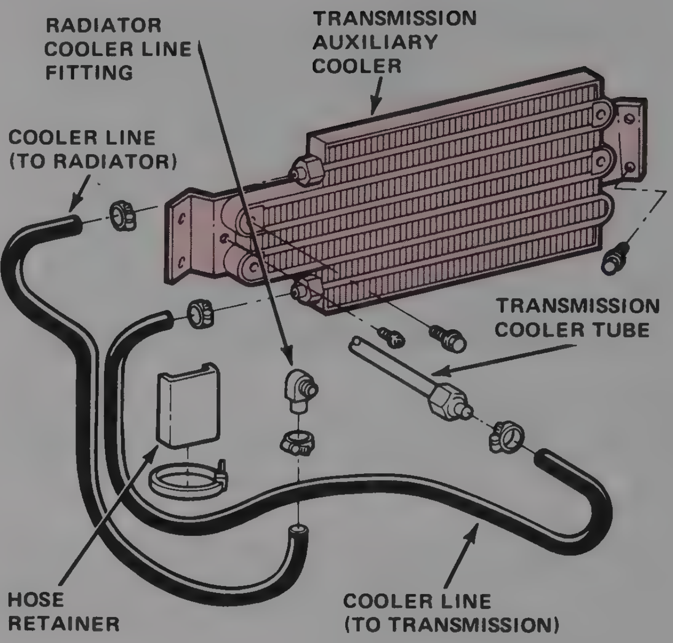

RADIATOR COOLER LINE FITTING
TRANSMISSION AUXILIARY COOLER
COOLER LINE (TO RADIATOR)
TRANSMISSION COOLER TUBE
HOSE RETAINER
COOLER LINE (TO TRANSMISSION)

Fig. 28-50. An auxiliary transmission oil cooler. Note how hoses connect between radiator cooler line fitting and transmission cooler tube. (Jeep)

ALUMINUM CASTING WARNING

Automatic transmission cases and extension housings are made of lightweight materials. While quite suitable for their purpose, they require care in handling to avoid nicking, scratching, or burring machined surfaces. Threads are soft and easily stripped.

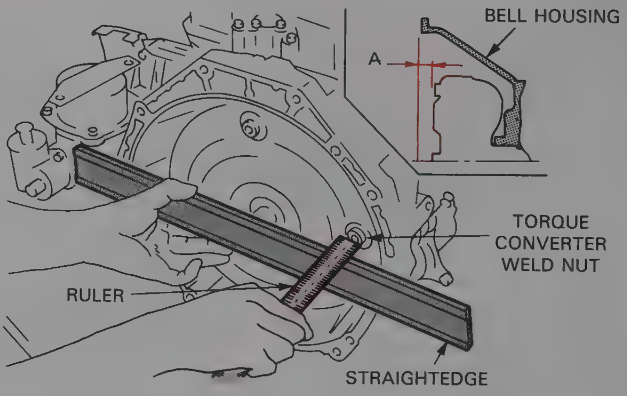


Fig. 28-51. By placing a straightedge across front of bell housing and measuring to torque converter weld nut, you can confirm that converter is fully seated. (Chrysler)

Always use a torque wrench to prevent stripping the threads. To prevent galling, dip the fastener threads in transmission fluid.

If a thread is stripped, use a Heli-Coil to make a repair (see chapter on fasteners and torque wrenches).

PUSHING CAR TO START

Some automatic transmissions permit push starting. Others do not.

If instructions supplied by the manufacturer indicate the car may be started by pushing, turn on the ignition. Place the selector lever in NEUTRAL. PUSH the car until road speed reaches about 20-25 mph (32-40 kph). At this point, move the selector into LOW range. The car should start.

The procedure just described is a general procedure for starting. Be sure to follow the manufacturer's specific recommendations.

Never tow a car to start. When the engine starts the resultant forward surge may cause the car to strike the towing vehicle.

TOWING A DISABLED VEHICLE WITH AN AUTOMATIC TRANSMISSION

On rear wheel drive vehicles, if the rear end, propeller shaft, and transmission are in SOUND condition, the car may be towed in NEUTRAL at a nominal speed. Generally, do not exceed 45 mph (72 kph) for a distance not greater than 50 miles (80 kilometers). Be sure to release the parking brake.

Some makers caution against towing for distances exceeding 12 to 15 miles (24 to 80 km). Check fluid level before towing.

When the transmission or drive line components are INOPERATIVE, the rear end must be raised clear of the road. Car may be towed without raising rear wheels by removing propeller shaft at the differential end. Tie shaft up out of the way securely.

Front-wheel drive vehicles should have the driving wheels raised off the road or placed in wheel dollies to tow.

Four-wheel drive vehicles require that a drive line be removed on some units, and that the wheels are placed in dollies. Others can be towed with all four wheels on the road by placing transmission in park and transfer case in neutral. Towing speed is generally around 30 mph (48 kph) with a distance of around 15 miles (24 km).

Remember that whenever there are drive line, wheel bearing, propeller shaft, or transmission problems, use wheel dollies or lift the effected end so that towing does not cause damage! Always follow car manufacturer's recommended towing method.

NEVER use the steering column (ignition lock) to hold the wheels in a straight ahead position. Damage to the lock and steering column is likely. Use an approved steering wheel clamping tool. ALWAYS use a safety chain or strap. Fig. 28-52 illustrates a typical tow truck attaching method for the front and rear of the same vehicle. Do not allow passengers in the towed vehicle.

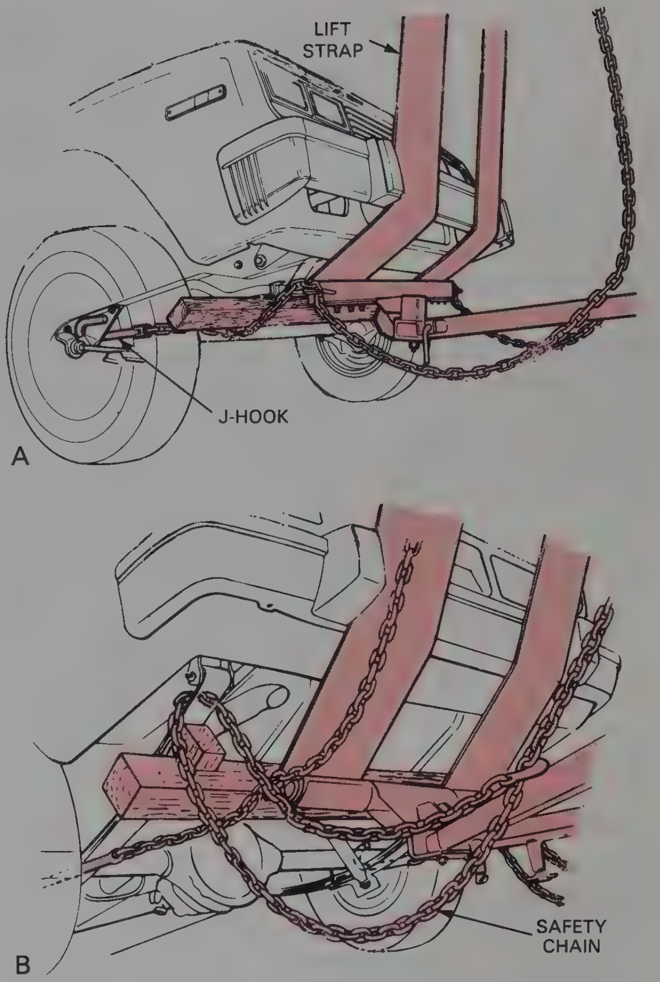


Fig. 28-52. Tow truck attachment methods for the same vehicle. Note the use of J-hooks and safety chain. A—Front of car. B—Rear of car. (AMC)

SUMMARY

A large percentage of transmission problems can be solved by in-car service procedures.

Current practice is to use three or four speed automatic transmissions utilizing a standard or lockup torque converter, compound planetary gearset, two or more clutches, and one or more bands.

The torque converter drives the transmission either directly, with a multiple link chain, or with gears.

Transmissions vary from year to year and from model to model. Always use manufacturer's service manual for exact repair and adjustment procedures.

Fluid level is critical. Overfilling causes aeration, leaking, and poor operation. A low level causes overheating and slipping.

When checking fluid level, make certain car is level, lever in N or P, fluid at operating temperature, engine idling, and that dipstick enters to full depth. Move selector through all ranges. Then check level. Do not allow dirt to enter fill pipe.

Check fluid for odor, discoloration, aeration, and signs of water.

Use care when running the engine with the car in gear. Apply both the emergency and service brakes. When idling with lever in park or neutral, set emergency brake and block wheels.

Some makers recommend periodic draining of fluid. Others do not. When draining fluid, it should be at operating temperature. Be careful to avoid burns.

To detect leaks, clean off the transmission and converter housing. Run the engine and check for evidence of red colored transmission fluid. A black light is helpful in locating leaks. Some leaks may be repaired without transmission removal.

Porous castings can often be repaired with epoxy resin.

The extension housing rear seal and bushing can often be replaced without pulling the housing. Removal of housing is required in some instances.

The engine must be in good condition and properly tuned before diagnosing transmission problems.

The mechanic should have the tools required to perform accurate transmission diagnosis, adjustment, and repair.

Shift linkage must be adjusted accurately. Engine mounts must be in good condition to prevent altering linkage adjustment.

Accelerator pedal height, carburetor, TV, and downshift linkage adjustment must be exact.

Carburetor anti-stall dashpot must be carefully adjusted. Adjust downshift switch if needed.

Check operation of neutral safety switch. Adjust or replace as needed.

When conducting a stall test, apply both parking and service brakes. Do not operate at full throttle for longer than 5 seconds. Operate engine in neutral to cool fluid between stall test periods.

Transmission fluid must be at operating temperature before conducting pressure tests. The rpm, drive range, and road speed are important in determining pressure.

Shift points must occur at recommended speeds. Shifts must be smooth and positive.

Some transmission designs require periodic band adjustments. Adjust very carefully — exactly as specified. Improper adjustment can cause serious damage.

Some governors may be exposed by removing the extension housing while others are covered with a removable plate.

The control valve body may be removed by draining the fluid and dropping the pan. Band and clutch action can be checked with air pressure on some transmissions. Use clean, dry air.

When pulling a transmission, be careful to avoid springing the drive plate. Use a safety chain to secure the transmission to the jack. Remove converter and transmission as an assembly. Some front-wheel drive vehicles require the removal of the engine with the transmission. Others must have engine properly supported before transmission removal.

Use a retaining bar or clip to prevent the converter from dropping off. Mark drive plate and converter.

Always flush the oil cooler and lines before connecting to a new or repaired transmission. Reverse flush with clean solvent followed with transmission fluid. Use care to align marks and avoid damage to the drive plate during transmission installation. Torque all fasteners. Dip fastener threads in fluid before installing. Repair stripped threads with Heli-Coils.

Always push car unless manufacturer recommends otherwise. Never tow to start. When towing, tow in neutral. Do not exceed 45 mph (72 kph) or distance recommended by maker—(usually around 50 miles or 80 km). If transmission or drive components are inoperative, raise drive wheels for towing. Lash steering wheel.

PROBLEM DIAGNOSIS

The variety of transmission types and models coupled with yearly modifications, make it impractical to formulate a generalized diagnosis chart of significant value.

As with overhaul techniques and procedures, the use of the maker's service manual is recommended. It will contain a comprehensive diagnosis chart or guide that applies to the transmission concerned.

The type of diagnosis guide, shown in Fig. 28-53, is very handy. The various conditions are listed along with possible corrections. The reasons or corrections are broken down into three groups. GROUP 1: corrections may be made on the car without removing the transmission oil pan. GROUP 2: corrections require draining the fluid and removing the pan. GROUP 3: corrections require transmission removal. Correction code letters are arranged in the order in which corrections or inspections are made. See Fig. 28-53.

Whenever possible, talk to the owner regarding transmission performance. It is a good idea to have the owner present during the road test. This will enable the owner to point out exact symptoms.

There are many times when the supposed "problem" is actually a normal condition. In such cases, a TACTFUL explanation of transmission operation will be all the repair needed.

ROAD TESTING

Operate the car (check fluid level before road test) in all the ranges. Check upshifts, downshifts, and forced (kickdown) downshifts in the various ranges. Shifts must be smooth, positive, and should occur at the recommended speeds. Check for noise and vibration.

Some shops employ the use of road test charts such as that pictured in Fig. 28-54. The use of such a chart

CONDITIONS	CORRECTIONS		
ENGAGEMENTS	**Group 1**	**Group 2**	**Group 3**
Harsh	B C D	L S	c f
Delayed Forward	A B C D	K L S	a
Delayed Reverse	A C D F	K L S	a
None	A B C J	K L S	a k l m o
No Forward D-1	A C	K L S	a b i
No Forward D-2	A B C	K L S	a b
No Reverse	A B C F E	O K S	a e h
No Neutral	C	L S	c
UPSHIFTS			
No 1-2	A C E	M K L N S	a y
No 2-3	A C E	L N S	a e t y
Shift Points Too High	A B C E	L S	a
Shift Points Too Low	A B E	L S	a
UPSHIFT QUALITY			
1-2 Delayed Followed Close By 2-3 Shift	A B C E	M K L N S	a b g
2-3 Slips	A B C E	K L N S	a e g t
1-2 Harsh	A B C E	M L S	b
2-3 Harsh	A B C E	M L S	f
1-2 Ties Up	A F	L S	f j
2-3 Ties Up	A C	M N	
DOWNSHIFTS			
No 2-1 in D-1	A B C E	L S	i y
No 2-1 in L-Range	A B C E	L O S	h y
No 3-2	A B E	L N S	g y
Shift Points Too High	A B C E	L S	a
Shift Points Too Low	A B C E	L S	a

CONDITIONS	CORRECTIONS		
FORCED DOWNSHIFTS	**Group 1**	**Group 2**	**Group 3**
2-1 Slips	A B C	S	b i
3-2 Slips	A B C	M K L N S	a e g t
3-1 Shifts Above — mph.	C E	K L N S	a g
2-1 Harsh			a b i
3-2 Harsh	A B C	M L N S	e f
REVERSE			
Slips Or Chatters	A B C F	O K L S	a c e h t
Tie Up	A	M N L S	a c
LINE PRESSURE			
Low Idle Pressure	A C D E	K L S	a m
High Idle Pressure	A B	L S	
Low Stall Pressure	A B E	K L S	a m y
High Stall Pressure	A B	L S	
STALL SPEED			
Too Low (200 RPM Or More)	H		o
Too High D-1	A B C J	K L S	u v a b i k o
Reverse Too High	A B C F J	K L O S	u v h e k o
OTHERS			
No Push Starts	A		n
Poor Acceleration	H		y o
Noisy in Neutral		S	f p d o
Noisy in Park		S	p d o
Noisy in All Gears		S	p r o
Noisy in 1st & 2nd Gear Only			p r w
Park Brake Does Not Hold	C	Q	q
Oil Out Breather	A G E	K L	a n x
Oil Out Fill Tube	A G I	K	a n x
Ties Up in Low, 1st Gear		M K L N S	f a
Ties Up in D-1, 1st Gear		M K L N S	f a
Ties Up in D-1 or D-2 2nd Gear	F C	L O S	f a j
Ties Up in D-1 or D-2, 3rd Gear	F C	MKLNOS	f a j

CORRECTION CODE KEY

Group 1—On Car Without Draining or Removing Oil Pan

A. Check oil level
B. Check oil pressure (gauges)
C. Manual linkage adjustment
D. Engine idle speed
E. Governor inspection
F. Rear band adjustment
G. Check dipstick length
H. Engine tune-up
I. Breather restricted
J. Broken propeller shaft or axle shaft

Group 2—On Car After Draining and Removing Oil Pan

K. Oil tubes missing or damaged
L. Valve body attaching bolts loose or missing
M. Front band adjustment
N. Front servo—remove, disassemble, and inspect
O. Rear servo—remove, disassemble, and inspect
P. Tube or servo seal rings missing, broken, leaking
Q. Parking linkage inspection
R. Pressure regulator (V-8)
S.
    1. Remove control valve assembly and inspect for loose screws.
    2. Replace control valve if no defects in Step 1.
    NOTE: Road test car after Step 1 if defect is corrected. Road test car after control valve replacement.

Group 3—Bench Overhaul

a. Sealing rings missing or broken
b. Front clutch slipping, worn plates, or faulty parts
c. Front clutch seized or distorted plates
d. Front clutch hub thrust washer missing (detectable in N, P, R only)
e. Rear clutch slipping, worn, or faulty parts
f. Rear clutch seized or distorted plates
g. Front band worn or broken
h. Rear band worn or broken
i. One-way (sprag) clutch slipping or incorrectly installed
j. One-way (sprag) clutch seized
k. Broken input shaft
l. Front pump drive tangs or converter hub broken
m. Front pump worn
n. Rear pump
o. Converter
p. Front pump
q. Parking linkage
r. Planetary assembly
s. Fluid distributor sleeve in output shaft (V-8)
t. Rear clutch piston ball check leaks
u. Broken output shaft
v. Broken gears
w. Forward sun gear thrust washer missing
x. Forward breather baffle missing
y. Output shaft plug missing (6-cyl.)

Fig. 28-53. Typical automatic transmission diagnosis guide. This guide is from manufacturer's service manual and applies to a specific transmission model only. (American Motors)

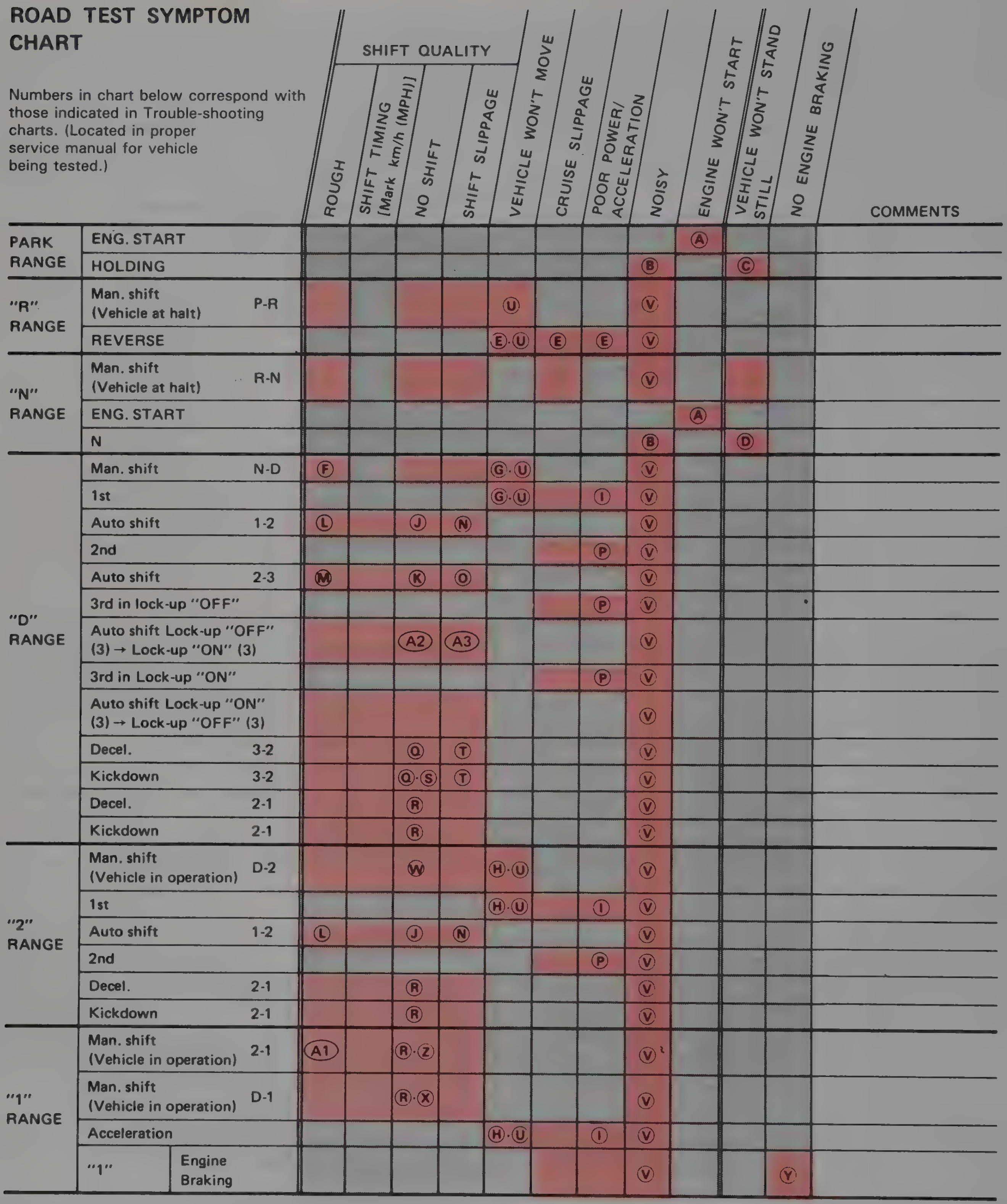
insures that all pertinent checks are made. It also provides the mechanic with a written record that is helpful for diagnostic purposes. Shift points and shift patterns obviously must relate to the transmission being tested.

Perform each check or adjustment carefully. An error, even though small, can often seriously upset transmission performance.

Remember that in a series of diagnostic steps, the accuracy of each check and adjustment can be completely dependent on the preceding steps. MAKE EACH CHECK AND ADJUSTMENT WITH CARE.

KNOW THESE TERMS

Torque converter, Compound planetary gearset, Variable pitch stator, Sun gear, Planet carrier, One-



ROAD TEST SYMPTOM CHART

Numbers in chart below correspond with those indicated in Trouble-shooting charts. (Located in proper service manual for vehicle being tested.)

			SHIFT QUALITY											
			ROUGH	SHIFT TIMING [Mark km/h (MPH)]	NO SHIFT	SHIFT SLIPPAGE	VEHICLE WON'T MOVE	CRUISE SLIPPAGE	POOR POWER/ ACCELERATION	NOISY	ENGINE WON'T START	VEHICLE WON'T STAND STILL	NO ENGINE BRAKING	COMMENTS
PARK RANGE	ENG. START										Ⓐ			
	HOLDING									Ⓑ		Ⓒ		
"R" RANGE	Man. shift (Vehicle at halt)	P-R					Ⓤ			Ⓥ				
	REVERSE						Ⓔ·Ⓤ	Ⓔ	Ⓔ	Ⓥ				
"N" RANGE	Man. shift (Vehicle at halt)	R-N								Ⓥ				
	ENG. START										Ⓐ			
	N									Ⓑ		Ⓓ		
"D" RANGE	Man. shift	N-D	Ⓕ				Ⓖ·Ⓤ			Ⓥ				
	1st						Ⓖ·Ⓤ		Ⓘ	Ⓥ				
	Auto shift	1-2	Ⓛ		Ⓙ	Ⓝ				Ⓥ				
	2nd								Ⓟ	Ⓥ				
	Auto shift	2-3	Ⓜ		Ⓚ	Ⓞ				Ⓥ				
	3rd in lock-up "OFF"								Ⓟ	Ⓥ				
	Auto shift Lock-up "OFF" (3) → Lock-up "ON" (3)				(A2)	(A3)				Ⓥ				
	3rd in Lock-up "ON"								Ⓟ	Ⓥ				
	Auto shift Lock-up "ON" (3) → Lock-up "OFF" (3)									Ⓥ				
	Decel.	3-2			Ⓠ	Ⓣ				Ⓥ				
	Kickdown	3-2			Ⓠ·Ⓢ	Ⓣ				Ⓥ				
	Decel.	2-1			Ⓡ					Ⓥ				
	Kickdown	2-1			Ⓡ					Ⓥ				
"2" RANGE	Man. shift (Vehicle in operation)	D-2			Ⓦ		Ⓗ·Ⓤ			Ⓥ				
	1st						Ⓗ·Ⓤ		Ⓘ	Ⓥ				
	Auto shift	1-2	Ⓛ		Ⓙ	Ⓝ				Ⓥ				
	2nd								Ⓟ	Ⓥ				
	Decel.	2-1			Ⓡ					Ⓥ				
	Kickdown	2-1			Ⓡ					Ⓥ				
"1" RANGE	Man. shift (Vehicle in operation)	2-1	(A1)		Ⓡ·Ⓩ					Ⓥ				
	Man. shift (Vehicle in operation)	D-1			Ⓡ·Ⓧ					Ⓥ				
	Acceleration						Ⓗ·Ⓤ		Ⓘ	Ⓥ				
	"1"	Engine Braking								Ⓥ			Ⓨ	

Fig. 28-54. One form of transmission road test chart. Use one for exact transmission being tested. (Nissan)

way clutch, Governor, Valve body, "Lock up" torque converter, Vacuum modulator, Automatic transmission fluid (ATF), Black light, TV linkage, Barometric pressure sensitive bellows, Downshift rod, Downshift switch, Anti-stall dashpot, Neutral safety switch, Stall test, Shift point, Flexible drive plate, Turbine, Stator, Impeller, Closed-end rivet, Apply servo, Release servo, Air pressure check, Parking pawl, Multiple link chain, Room temperature vulcanizing (RTV) silicone, Auxiliary transmission cooler.

QUIZ - Chapter 28

1. Most transmission problems require transmission removal for correction. True or False?
2. Most transmissions are of the same design. True or False?
3. Transmission fluid level should be kept:
   a. On the full mark.
   b. Between the ADD and the FULL marks.
   c. Slightly below the ADD mark.
   d. Slightly above the FULL mark.
4. Check fluid level when the fluid is at Normal operating tempeture.
5. When checking fluid level, shift lever should be in Neutral or parKing position.
6. Automatic transmissions require special fluid. It is identified by the following:
   a. BD - A - (numbers) - A.
   b. AQ - A - (numbers) - B.
   c. AQ - TAF - (numbers) - A.
   d. AQ - ATF - (numbers) - A.
7. All transmissions should be drained about every 24,000 miles (38 600 km). True or False?
8. Periodic changing of transmission fluid requires that the converter be drained also. True or False?
9. Drain fluid while it is Normal tempature.
10. When replacing a converter plug, always tighten with great force. True or False?
11. Fluid, while draining, can cause serious burns. True or False?
12. Transmission fluid installed at the factory is generally:
    a. A blue color.
    b. A green color.
    c. A red color.
    d. Clear.
13. Before trying to pinpoint a leak, clean on underparts engine the underside of the converter housing and the Transmission.
14. Leaks always require transmission removal. True or False?
15. A porous casting can often be repaired by cleaning and covering the leaking area with epoxy risin.
16. Engine idle and speed must be alright before conducting diagnostic tests on the transmission.
17. Sagging engine mounts can alter:
    a. TV rod adjustment.
    b. Downshift rod adjustment.
    c. Selector rod adjustment.
    d. All of above.
18. A downshift Switch is sometimes used in preference to a downshift rod.
19. Linkage adjustments are important in maintaining:
    a. Proper upshift points.
    b. Proper downshift points.
    c. Transmission service life.
    d. All of above.
20. The anti-stall dashpot prevents the downshift rod from striking the firewall. True or False?
21. The neutral safety switch operation should always be checked during any transmission inspection. True or False?
22. All transmissions should be stall tested. True or False?
23. The stall test is used to check the operation of the Clutches, Band, and one-way clutch.
24. When stall testing, never maintain the full throttle position for longer than:
    a. 5 seconds.
    b. 5 minutes.
    c. 45 seconds.
    d. 2 minutes.
25. The gauge generally required for oil pressure checks should read from zero to 3000 psi or 0-268 kPa.
26. Shift points depend upon several things. List three.
27. To make most band adjustments, loosen the locknut and bring the adjusting screw to proper torque. Then, while holding the screw at this point, tighten the locknut. True or False?
28. Some bands do not require periodic adjustments. True or False?
29. Following removal of the control valve body, it is possible (on some transmissions) to test the operation of the clutches and bands by applying air pressurre to the respective passageways in the case.
30. Always remove the converter:
    a. With the transmission.
    b. Before the transmission.
    c. After the transmission.
31. Always use a Safety Chain to secure the transmission to the jack.
32. The drive plate and coverter should be marked before removal to assure proper realignment upon installation.
33. Never allow the weight of the transmission and converter to rest on the Drive plate.
34. A retaining bar should be used to prevent the converter from dropping off the tranmission during removal.
35. Before installing a new or repaired transmission, the lines and oil cooler should be flushed.
36. Before starting a fastener in the transmission, ________ it in ________ ________ to prevent galling.
37. When trying to start a car, it is better to tow it. True or False?
38. When the transmission is inoperative, the car may be towed if you do not exceed 40 mph (64 kph). True or False?

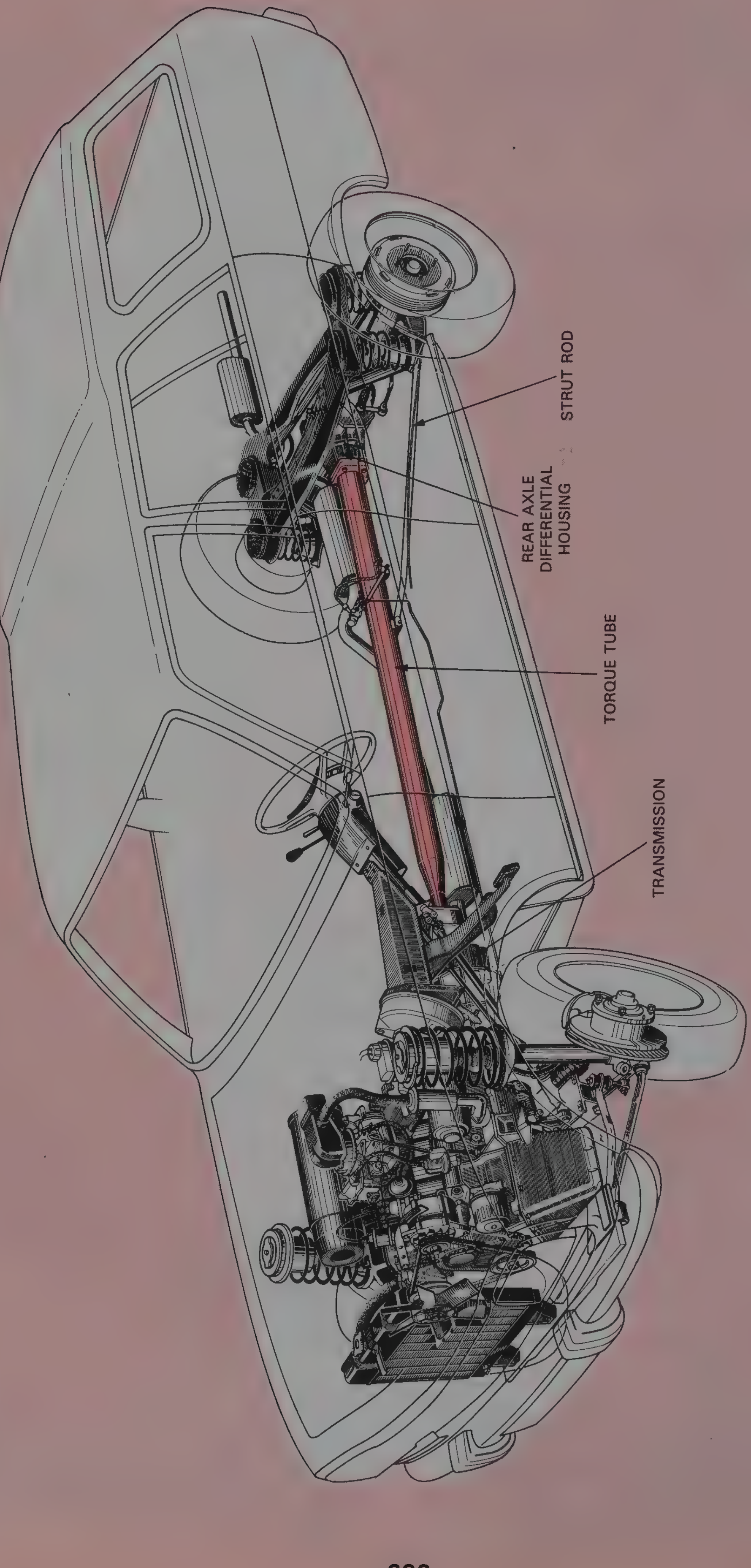
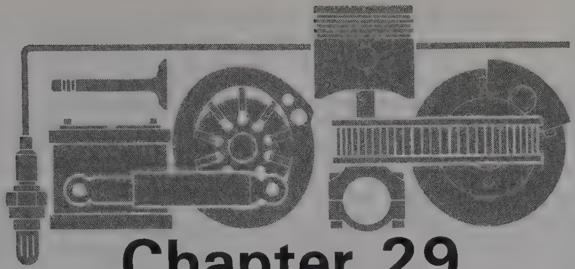

STRUT ROD
REAR AXLE DIFFERENTIAL HOUSING
TORQUE TUBE
TRANSMISSION

Fig. 29-1. One type of torque tube drive. Note that tube is rigidly attached to rear axle housing. Front of tube pivots in a special joint at end of transmission. (Peugeot)



Chapter 29

DRIVE LINE AND UNIVERSAL JOINT SERVICE

After studying this chapter, you will be able to:

☐ Explain the construction and operation of one and two-piece drive lines.
☐ Service one and two-piece drive lines.
☐ Describe cross and roller and ball and trunnion universal joints.
☐ Service universal joints.
☐ Diagnose drive line and universal joint problems.

BASIC DRIVE LINE TYPES

The TORQUE TUBE drive encloses the propeller shaft inside a steel torque tube. One end of the tube is bolted to the differential housing. The other is attached to the rear of the transmission by means of a torque ball (ball and socket) arrangement.

Drive force from the rear wheels is applied to the axle housing through the torque tube to the transmission. The torque tube also controls rear axle housing "windup" (housing attempting to rotate) during acceleration, deceleration, and braking. See Fig. 29-1.

Another setup uses a shortened torque tube that runs from the rear axle to a flexible front support. A regular open propeller shaft connects the transmission to the shortened section. Study Fig. 29-2.

A somewhat different torque control arrangement is pictured in Fig. 29-3. Instead of a torque tube sur-

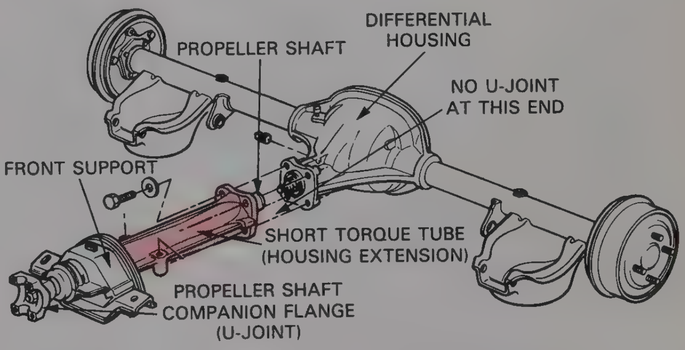

DIFFERENTIAL HOUSING
PROPELLER SHAFT
NO U-JOINT AT THIS END
FRONT SUPPORT
SHORT TORQUE TUBE (HOUSING EXTENSION)
PROPELLER SHAFT COMPANION FLANGE (U-JOINT)

Fig. 29-2. A short torque tube arrangement. A regular open propeller shaft connects transmission to torque tube shaft. (Chevrolet)

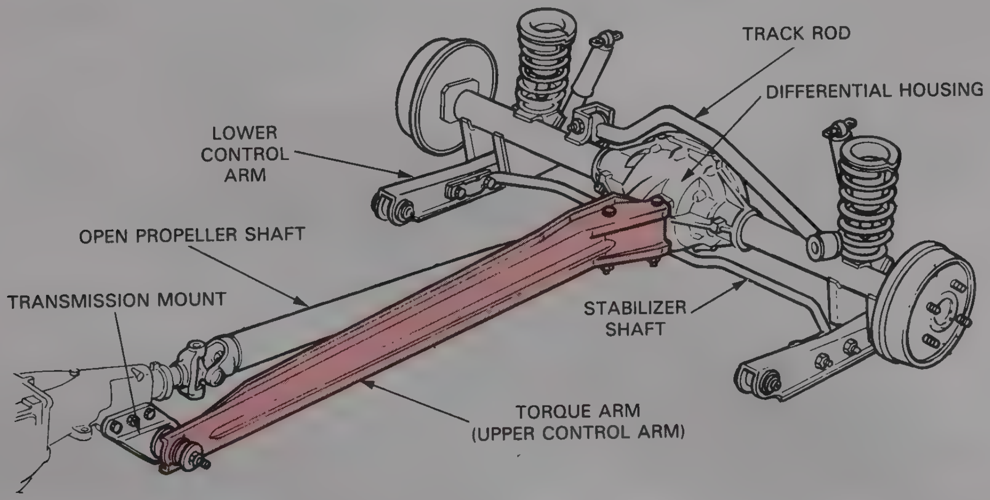

TRACK ROD
DIFFERENTIAL HOUSING
LOWER CONTROL ARM
OPEN PROPELLER SHAFT
TRANSMISSION MOUNT
STABILIZER SHAFT
TORQUE ARM (UPPER CONTROL ARM)

Fig. 29-3. This drive arrangement uses an open propeller shaft (Hotchkiss type) in conjunction with a torque arm. Note how arm is attached. (Chevrolet)

rounding the propeller shaft, a separate torque arm is employed. One end is attached rigidly to the differential housing. The other end is attached to a rubber bushed mount on the transmission. The open propeller shaft uses universal joints at both ends, Fig. 29-3.

The HOTCHKISS drive uses an open propeller shaft. It may be of a one or more piece design.

Drive force and axle housing windup is handled by leaf springs or by control arms. A typical Hotchkiss drive setup is pictured in Fig. 29-4.

A one-piece propeller shaft is illustrated in Fig. 29-5. Note the slip yoke to allow for lengthwise movement between the transmission and rear axle housing.

In this setup, the slip yoke slides onto the splined transmission output shaft. The end yoke is attached to the differential pinion shaft or to the pinion shaft flange, depending on the design. See Fig. 29-5.

Some installations utilize a two-piece propeller shaft. This application requires the use of a center support bearing. Study the center support bearing arrangement in Fig. 29-6.

CROSS AND ROLLER UNIVERSAL JOINT

The CROSS AND ROLLER type of universal joint is widely used. Basic construction is shown in Fig. 29-7. Note how needle bearings are used to reduce friction.

An exploded view of the cross and roller type joint is pictured in Fig. 29-8.

The cross rollers can be retained by:

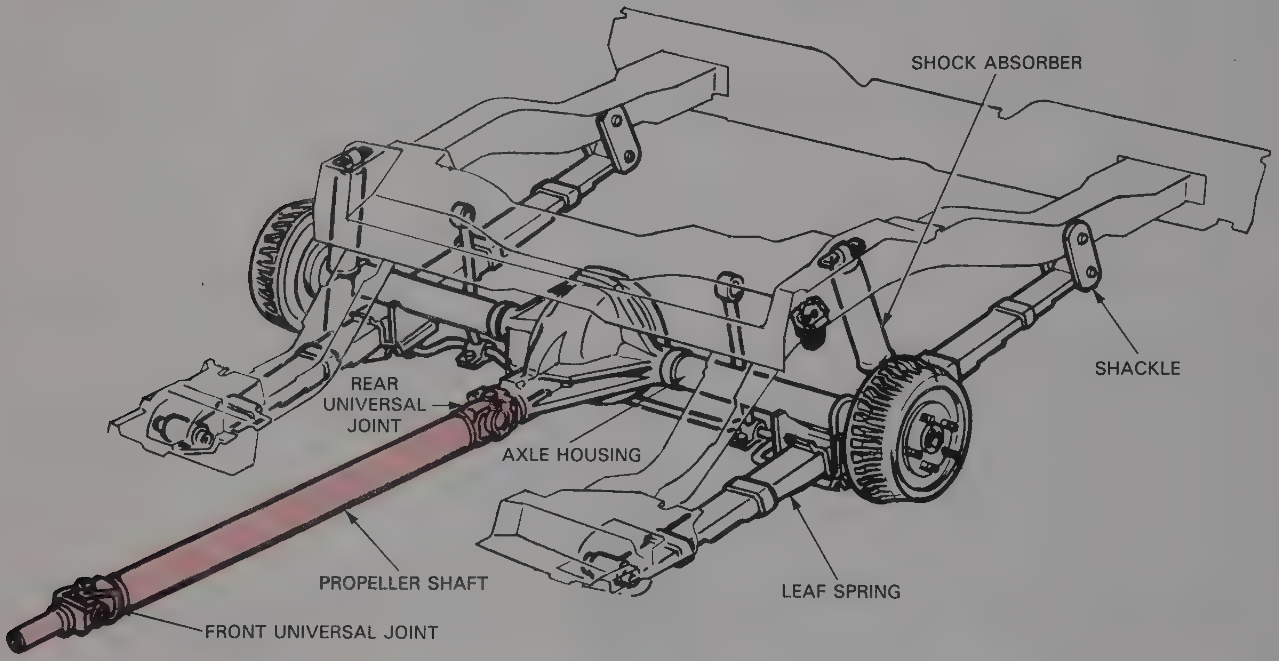

SHOCK ABSORBER
SHACKLE
REAR UNIVERSAL JOINT
AXLE HOUSING
PROPELLER SHAFT
LEAF SPRING
FRONT UNIVERSAL JOINT

Fig. 29-4. Hotchkiss drive setup. Springs transmit drive force to frame and also control rear housing torque forces. (Chevrolet)

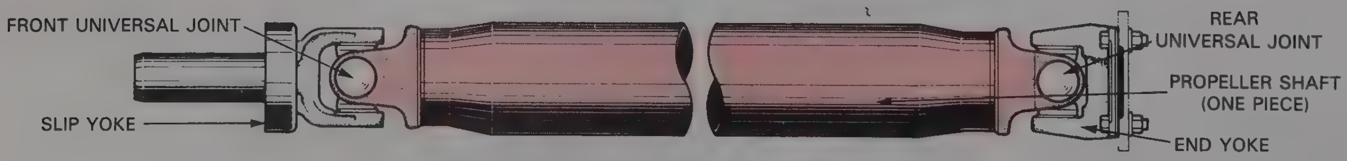

FRONT UNIVERSAL JOINT
SLIP YOKE
REAR UNIVERSAL JOINT
PROPELLER SHAFT (ONE PIECE)
END YOKE

Fig. 29-5. One-piece propeller shaft. (Toyota)

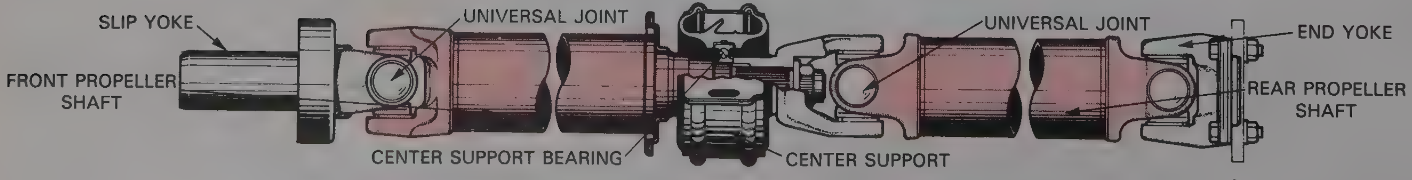

SLIP YOKE
FRONT PROPELLER SHAFT
UNIVERSAL JOINT
CENTER SUPPORT BEARING
CENTER SUPPORT
UNIVERSAL JOINT
END YOKE
REAR PROPELLER SHAFT

Fig. 29-6. Two-piece propeller shaft. Note use of center support bearing. (Toyota)

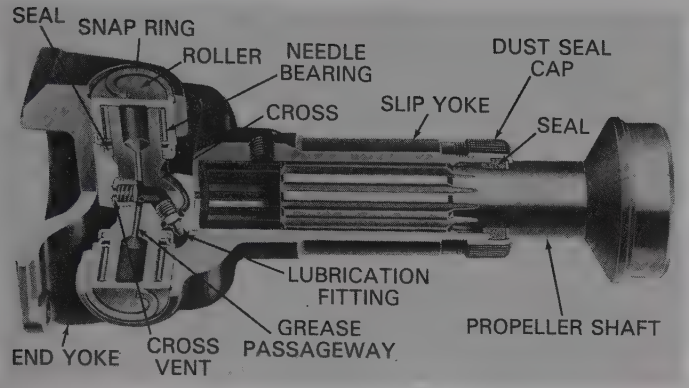

SEAL
SNAP RING
ROLLER
NEEDLE BEARING
CROSS
SLIP YOKE
DUST SEAL CAP
SEAL
LUBRICATION FITTING
GREASE PASSAGEWAY
PROPELLER SHAFT
END YOKE
CROSS VENT

Fig. 29-7. A basic cross and roller universal joint. Rollers are retained by snap rings. Note spring-loaded vent in cross. This vents excess pressure and grease. (Spicer)

1. Snap rings set into the yoke at the outer ends of the rollers, A and C, Fig. 29-9.
2. U-bolts passing around the roller and through the yoke, A, Fig. 29-9.
3. Snap rings that are set into a groove near the inner ends of the rollers, B, Fig. 29-9.
4. Flat plates, D, Fig. 29-9.
5. Wing type rollers in which the roller body has flanges through which bolts pass into the yoke, B, Fig. 29-9.

Note that where wing rollers, U-bolts, or clamps are used, the joint may be readily disassembled to permit removal of the propeller shaft. Refer to Fig. 29-9.

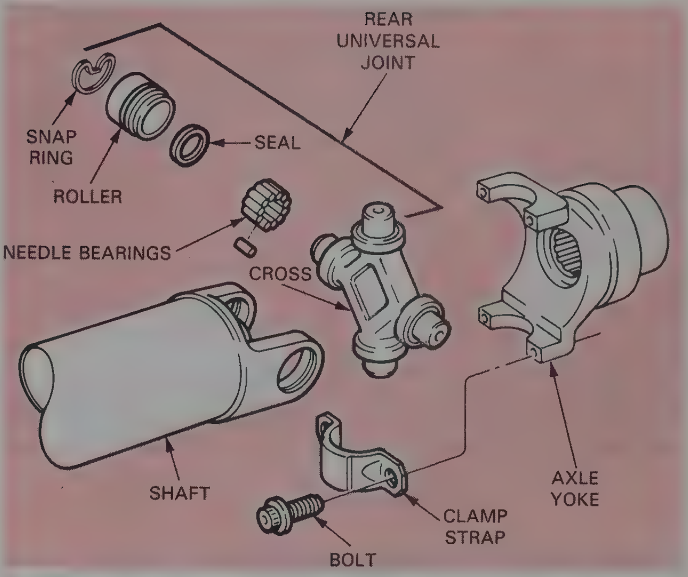

REAR UNIVERSAL JOINT
SNAP RING
SEAL
ROLLER
NEEDLE BEARINGS
CROSS
SHAFT
AXLE YOKE
CLAMP STRAP
BOLT

Fig. 29-8. Exploded view of a cross and roller universal joint. Note use of snap ring and clamp. (AMC)

Injection molded nylon rings are sometimes used to retain the rollers. When this type is disassembled, conventional rollers with snap rings are generally used for replacement. Driving the rollers out shears and ruins the nylon ring. A universal joint using injection moulded nylon to secure the rollers is pictured in Fig. 29-10.

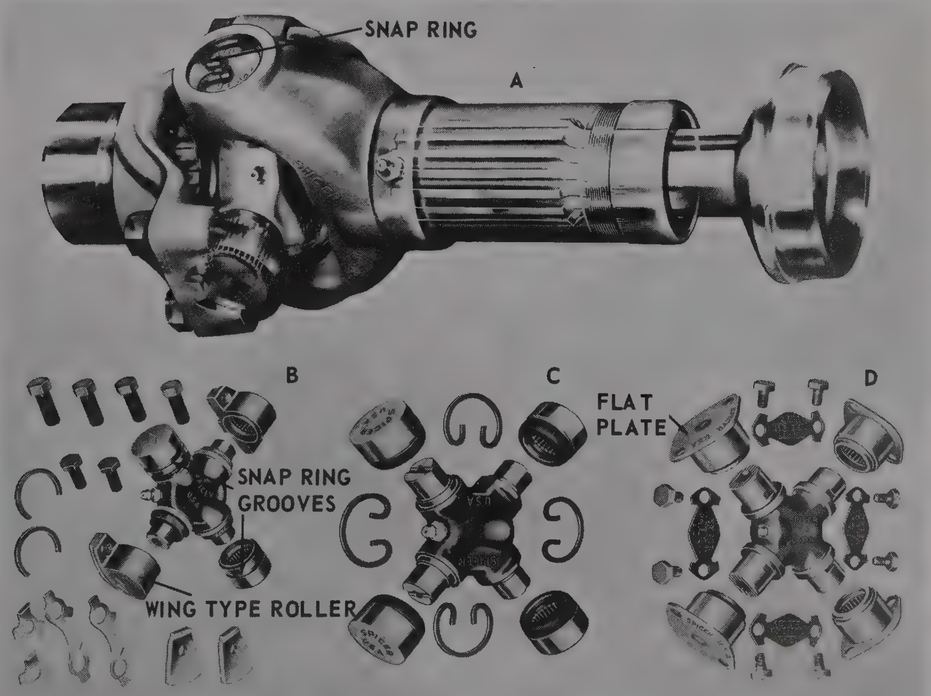

SNAP RING
A
B
C
D
FLAT PLATE
SNAP RING GROOVES
WING TYPE ROLLER

Fig. 29-9. Cross and roller universal joint showing various methods of retaining cross rollers. (Spicer)

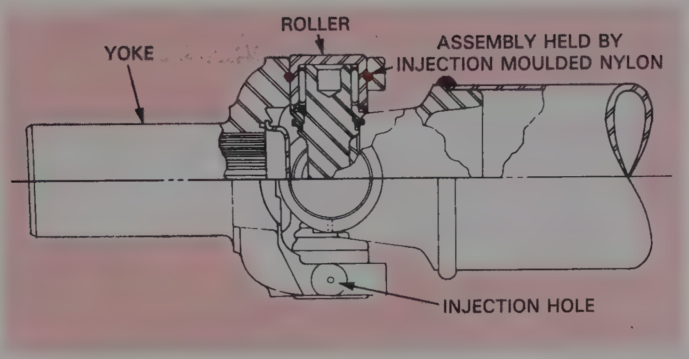

ROLLER
YOKE
ASSEMBLY HELD BY
INJECTION MOULDED NYLON
INJECTION HOLE

Fig. 29-10. Cutaway view of a universal joint assembly. Rollers are retained in yoke with injected liquid nylon. Nylon hardens in roller and corresponding yoke groove preventing separation. (Pontiac)

BALL AND TRUNNION UNIVERSAL JOINT

Ball and trunnion universal joint construction is shown in Fig. 29-11. Such a design permits some fore and aft movement within the joint itself thus eliminating the need of a sliding yoke slip joint.

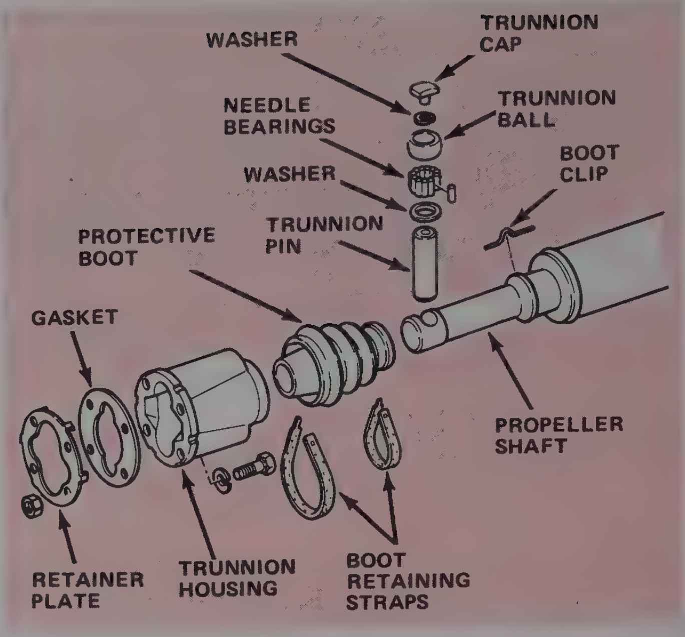

WASHER
TRUNNION CAP
NEEDLE BEARINGS
TRUNNION BALL
BOOT CLIP
WASHER
TRUNNION PIN
PROTECTIVE BOOT
GASKET
PROPELLER SHAFT
RETAINER PLATE
TRUNNION HOUSING
BOOT RETAINING STRAPS

Fig. 29-11. Exploded view of a ball and trunnion universal joint. (Jeep)

CONSTANT VELOCITY UNIVERSAL JOINT

A CONSTANT VELOCITY U-joint causes both input and output sides of the joint to rotate at the same speed throughout the full 360 deg. of rotation. It is made by connecting two single cross and roller type joints with a center yoke and using a centering socket yoke and socket support yoke.

The centering socket between the joints forces each half of the unit to rotate on a plane forming one half of total angle between propeller shaft and transmission or differential pinion shaft. See Figs. 29-12 and 29-13.

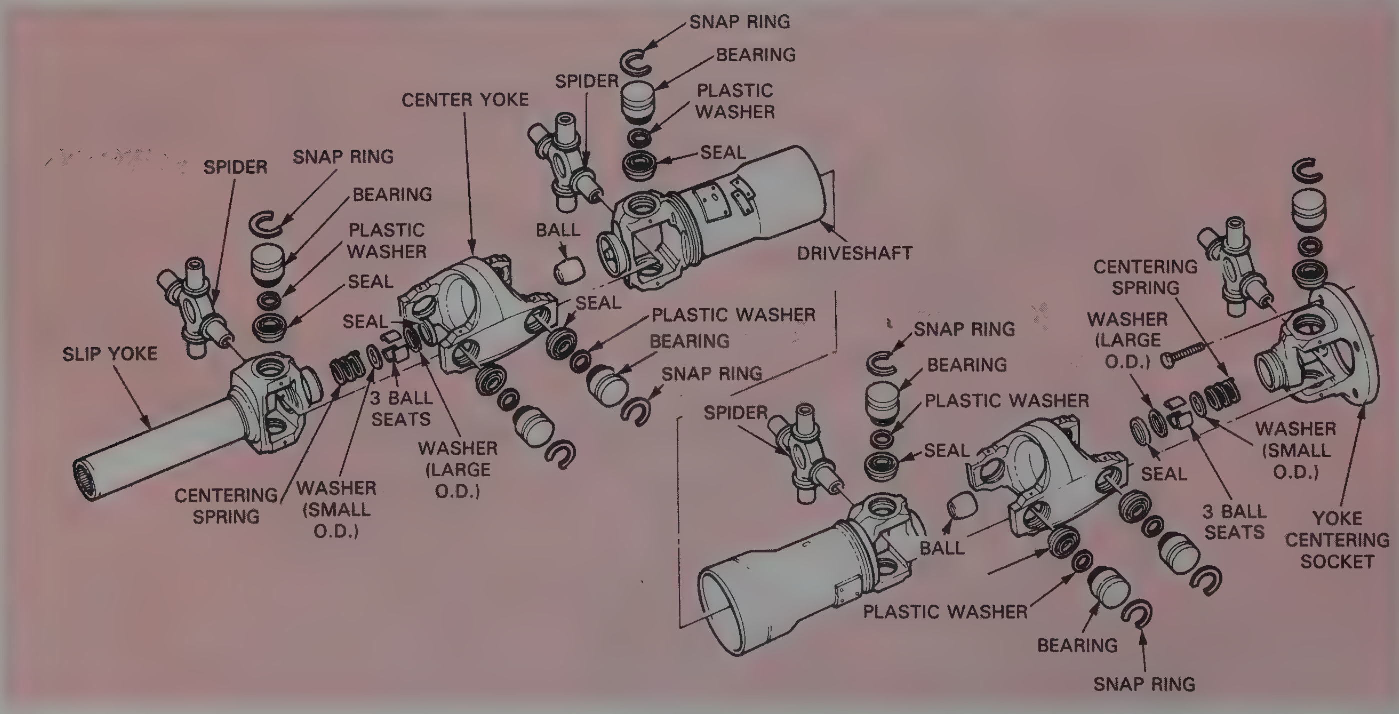

SNAP RING
BEARING
SPIDER
PLASTIC WASHER
CENTER YOKE
SEAL
SPIDER
SNAP RING
BEARING
PLASTIC WASHER
BALL
SEAL
DRIVESHAFT
SEAL
SEAL
PLASTIC WASHER
BEARING
SLIP YOKE
SNAP RING
3 BALL SEATS
WASHER (LARGE O.D.)
CENTERING SPRING
WASHER (SMALL O.D.)
CENTERING SPRING
SNAP RING
WASHER (LARGE O.D.)
BEARING
PLASTIC WASHER
SPIDER
SEAL
WASHER (SMALL O.D.)
SEAL
3 BALL SEATS
YOKE CENTERING SOCKET
BALL
PLASTIC WASHER
BEARING
SNAP RING

Fig. 29-12. Exploded view of a drive shaft and two constant velocity universal joints. Study part names and their locations. (Ford)

The use of a constant velocity joint produces a very smooth flow of power even over fairly acute driving angles. Look at Fig. 29-13. One or more constant velocity joints may be used. The single piece propeller shaft in Fig. 29-14 has two such joints.

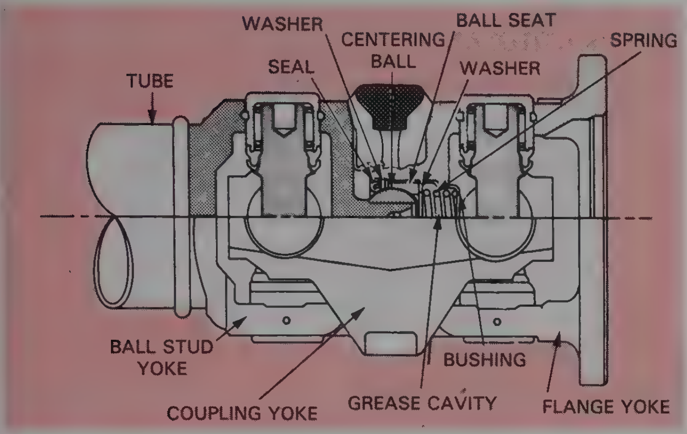

WASHER
CENTERING BALL
BALL SEAT
SPRING
SEAL
WASHER
TUBE
BALL STUD YOKE
BUSHING
COUPLING YOKE
GREASE CAVITY
FLANGE YOKE

Fig. 29-13. Cutaway view of a constant velocity universal joint. Note centering ball. (Chevrolet)

DRIVE AXLE UNIVERSAL JOINTS

Drive axle (sometimes called axle drive shaft, half-shaft, etc.) universal joints are used on certain front-wheel, rear wheel, and four-wheel drive vehicles. They allow the drive axle to move or be moved through many different directional changes. Fig. 29-15 depicts one particular front-wheel drive universal joint and axle assembly.

These joints are serviced in basically the same way as conventional ones. Be sure to use an appropriate service manual for the vehicle being repaired. Follow all instructions carefully. For more information, see Chapter 30.

REMOVING PROPELLER SHAFT

If a ball and trunnion U-joint is used, remove the trunnion body-to-transmission drive flange fasteners. Break (disassemble) the rear U-joint and remove the shaft.

Where cross and roller joints are used, study the arrangement to see which joint should be disassembled.

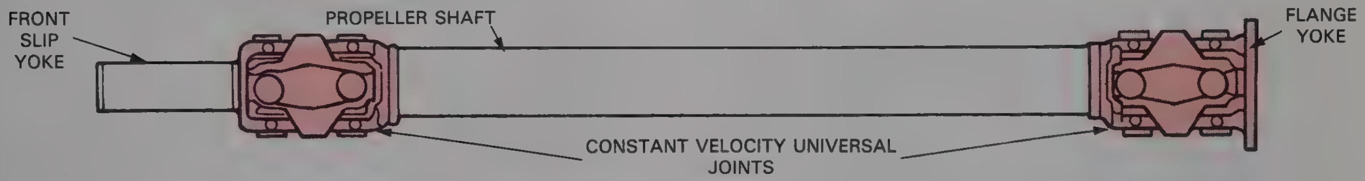

FRONT SLIP YOKE
PROPELLER SHAFT
FLANGE YOKE
CONSTANT VELOCITY UNIVERSAL JOINTS

Fig. 29-14. Single piece propeller shaft using two constant speed universal joints. (Cadillac)

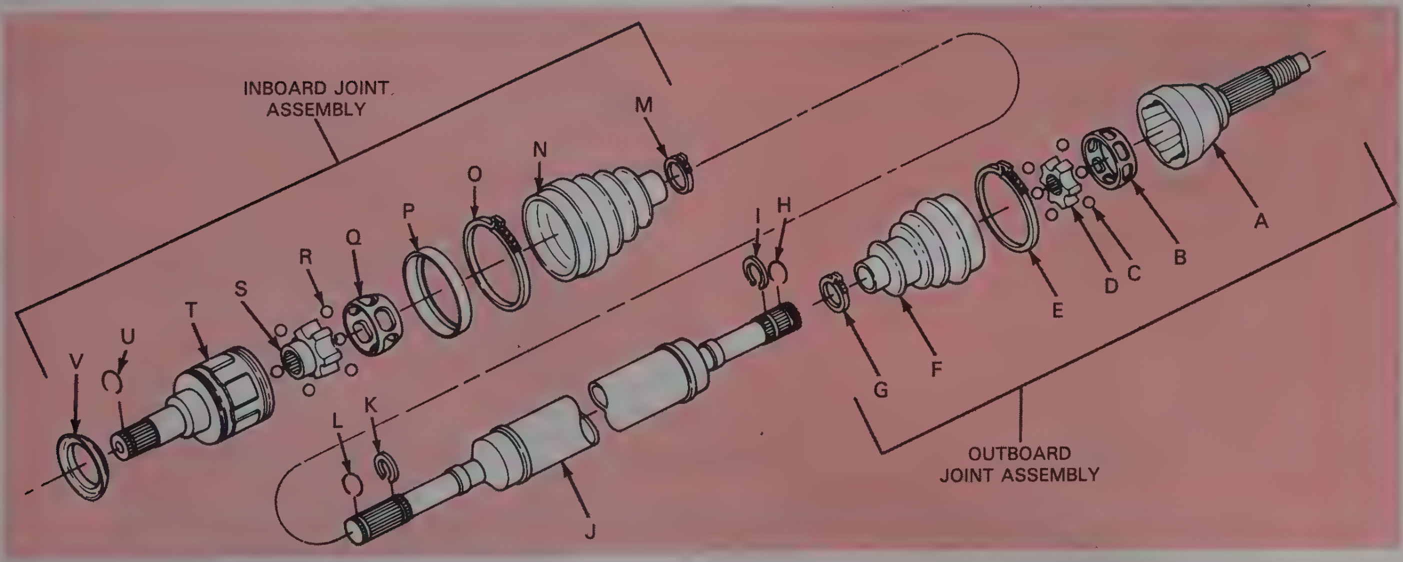

INBOARD JOINT ASSEMBLY
M
N
O
P
Q
R
S
T
U
V
I
H
A
B
C
D
E
F
G
K
L
J
OUTBOARD JOINT ASSEMBLY

Fig. 29-15. Exploded view of one type front-wheel drive axle and universal joint assembly. A—Outer bearing race and stub shaft assembly. B—Bearing cage. C—Ball bearings. D—Inner bearing race. E—Boot clamp (large). F—Boot. G—Boot clamp (small). H—Circlip. I—Stop ring. J—Interconnecting shaft. K—Stop ring. L—Circlip. M—Boot clamp (small). N—Boot. O—Boot clamp (large). P—Bearing retainer. Q—Bearing cage. R—Ball bearings. S—Inner bearing race. T—Outer bearing race and stub shaft assembly. U—Circlip. V—Dust deflector. (Ford)

The universal joint assembly utilizing wing rollers, or U-bolts to retain two of the rollers, will be the one to break. See Fig. 29-16.

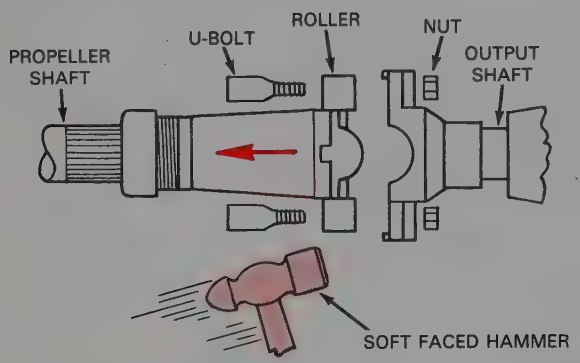


Fig. 29-16. Breaking U-joint so propeller shaft may be removed.

Some shafts employ flange yokes on one or both ends. In these cases, merely remove the flange fasteners. Such a flange yoke arrangement is shown in Figs. 29-13 and 29-14.

Never place a bar between cross and yokes to hold propeller shaft while removing U-joint fasteners. This practice can cause damage to the seals and seal surface. Mark parts to preserve balance and phasing.

Before disassembling a U-joint and removing the propeller shaft, mark the propeller shaft, slip yoke, flange yoke, and companion flange. Then the parts may be reassembled in exactly the same relative positions.

The yokes at both ends of the propeller shaft must be in the same plane. Yokes A and B in Fig. 29-17 are correctly aligned so that both will operate in the same plane.

When the yokes are permanently affixed to the ends of the shaft, do not be concerned about yoke alignment. Where a slip joint, as in Fig. 29-17, is placed between the shaft and one of the U-joints, it is possible to enter the splined stub shaft into the slip yoke in a number of positions.

Remember! Engage the stub shaft with the slip yoke so that both yokes are in the same plane. If the yokes are misaligned, joint phasing will be out and serious vibration can result.

DO NOT DROP ROLLERS

If the rollers are not retained on the cross with a thin strap, tape them on. This will keep them from dropping and possibly losing the needle bearings. See Fig. 29-18.

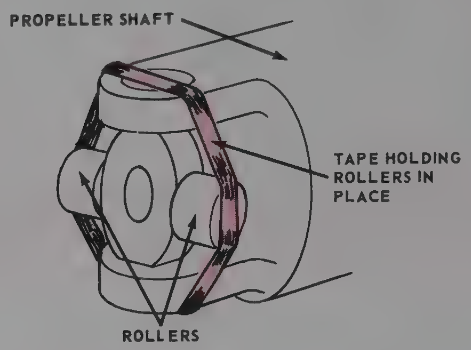


Fig. 29-18. Tape rollers to prevent dropping. This will also keep them on cross in original position.

SUPPORT PROPELLER SHAFT

After breaking a U-joint, let the shaft end down carefully. Do not allow the shaft to fall. Do not allow the shaft to hang supported by one U-joint. Never force the shaft to flex the U-joint beyond its capacity to swivel. Careless handling can cause severe damage to shaft and joints. Never bend a constant velocity joint to the limit of its travel.

When the shaft is long and fairly clumsy to handle, have another mechanic lend a hand during shaft removal and installation.

CENTER SUPPORT BEARING

If a two-piece shaft is employed, the center support bearing must be removed to permit shaft withdrawal.

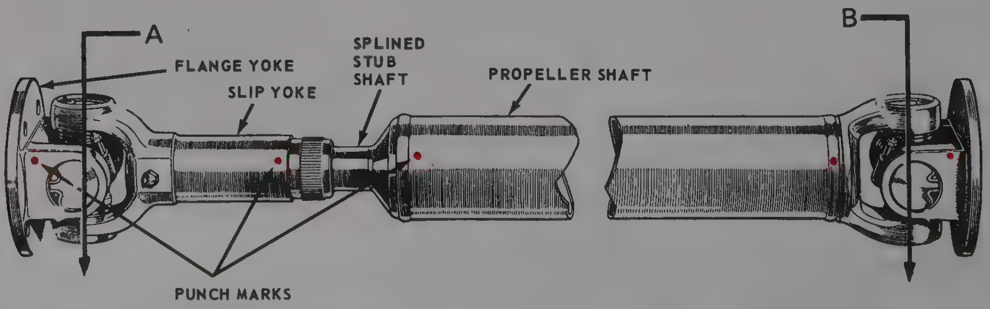


Fig. 29-17. Mark propeller shaft, slip yoke, and flange yoke before disassembly. Mark companion flange also. (British-Leyland)

Check between support and frame for the presence of shims. If used, replace shims when installing center support, Fig. 29-19.

Always check condition of the center support bearing before reinstalling. Lubricate.

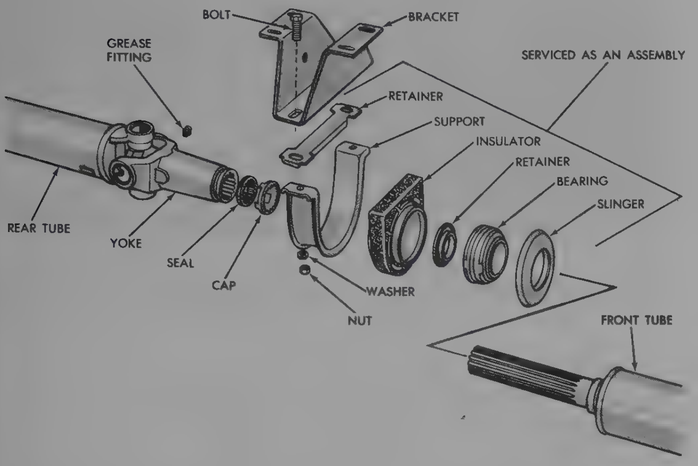

BOLT
BRACKET
GREASE FITTING
SERVICED AS AN ASSEMBLY
RETAINER
SUPPORT
INSULATOR
RETAINER
BEARING
SLINGER
REAR TUBE
YOKE
SEAL
CAP
WASHER
NUT
FRONT TUBE

Fig. 29-19. Exploded view of a center support bearing assembly. Note that bearing assembly must be serviced as a unit. (Chrysler)

PROTECT SLIP YOKE SURFACE

If the front shaft slip yoke engages the transmission output shaft, cover the slip yoke with cardboard or several layers of rags. This will protect the yoke from dirt and nicks.

When needed, place a spare yoke or special plug in the transmission to prevent fluid leakage while the shaft is removed.

REPAIRING CROSS AND ROLLER U-JOINT

If the rollers are held with snap rings at the outer edge, tap the roller INWARD a small amount to free the snap ring, Fig. 29-20. Use pliers to remove the snap rings, Fig. 29-21.

When the rollers are secured with snap rings that engage the roller on the inner side, tap the roller inward a small amount and drive the snap rings out with a thin punch, Figs. 29-22 and 29-23.

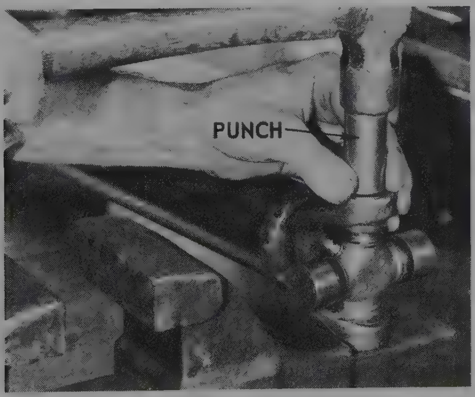


Fig. 29-20. Tap roller inward small amount to free snap ring. (Dana Corp.)

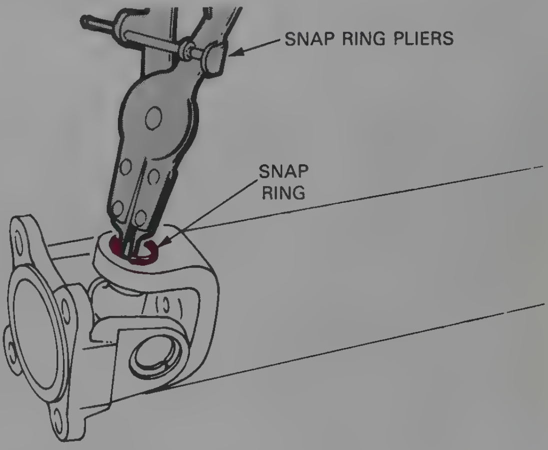

SNAP RING PLIERS
SNAP RING

Fig. 29-21. Removing snap ring with pliers after roller has been tapped inward. (Chrysler)

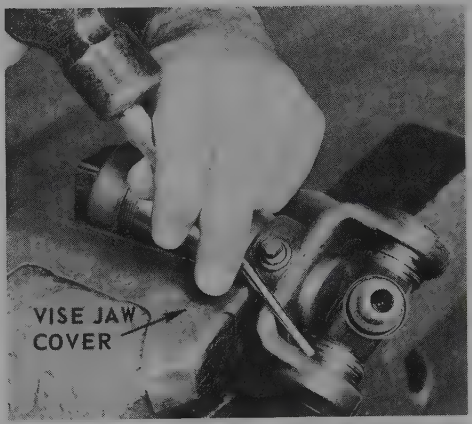

VISE JAW COVER

Fig. 29-22. Using thin nose punch to remove snap rings from rollers. Note use of protective vise jaw covers.

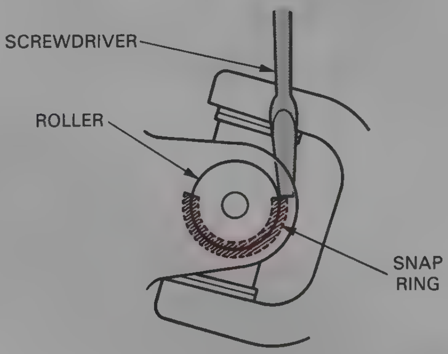

SCREWDRIVER
ROLLER
SNAP RING

Fig. 29-23. Using a screwdriver to force snap ring from roller. (Toyota)

Place the yoke between the jaws of a heavy vise. Adjust jaws so that yoke is just free to move. Rest cross trunnions on top of jaws. Use jaw covers to protect the cross trunnions.

Strike the yoke smartly with a lead, brass, or plastic hammer. This will drive the yoke downward, causing the cross to force the roller partway out of the yoke lug. Look at Fig. 29-24.

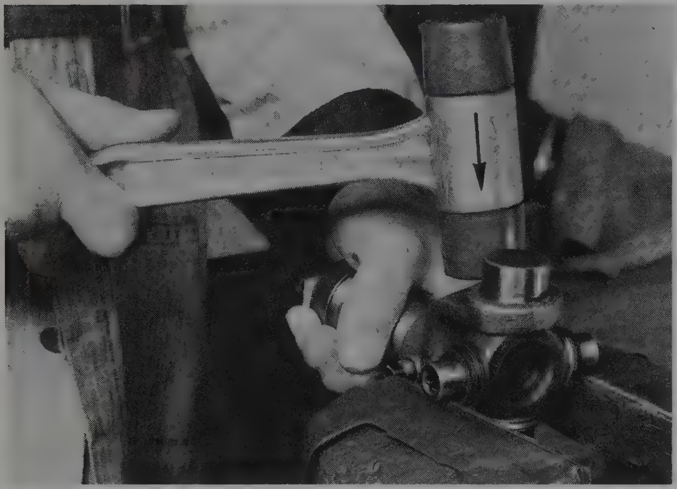


Fig. 29-24. Driving yoke downward to remove roller. (Dana Corp.)

The vise may also be used as a press by placing a small socket against one roller and a large socket against the yoke on the opposite side. As the vise is closed, the small socket will force the cross to push the opposite roller partway into the large socket, Fig. 29-25.

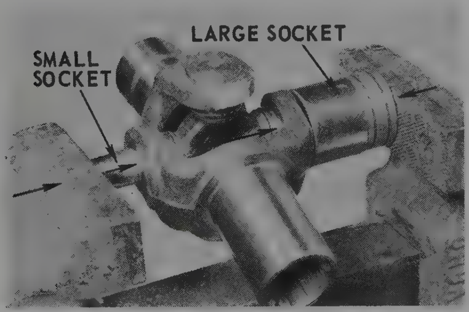


Fig. 29-25. Using vise and two sockets to force roller from yoke lugs. (American Motors)

When the roller is forced partway out, grasp the roller and strike the yoke to complete removal. Some rollers can also be removed (after loosening) with pliers. Do not spill the needle bearings when roller is free. See Figs. 29-26 and 29-27.

Force the cross in the opposite direction to remove the other roller. The cross may then be forced against one lug, tipped outward, and removed. Refer to Fig. 29-28.

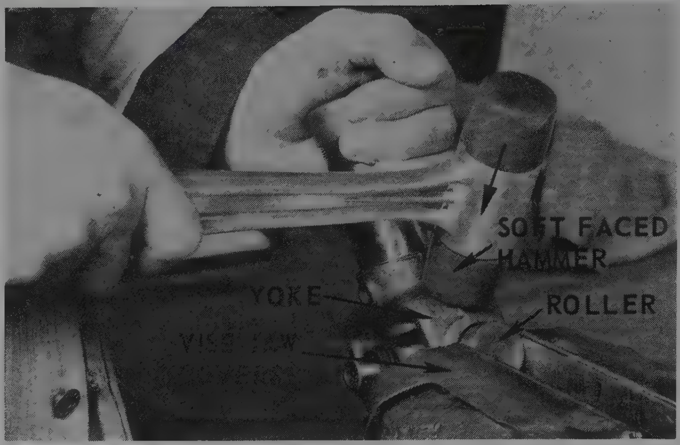


Fig. 29-26. Grasp protruding roller in vise and strike yoke to remove roller.

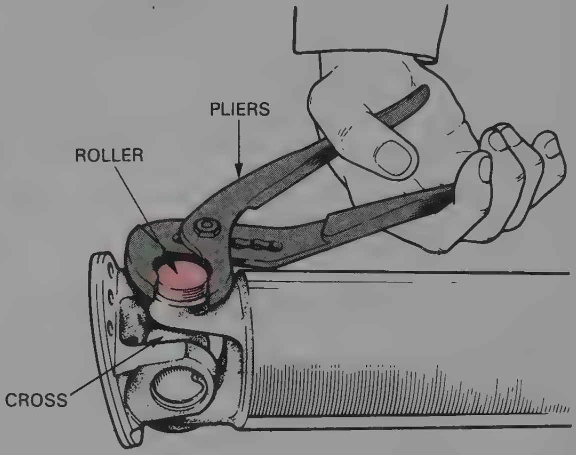


Fig. 29-27. Removing loosened roller with aid of pliers. (British-Leyland)

CLEANING AND INSPECTION

Wipe off the cross trunnions. If they are worn, discard the cross, rollers, and snap rings. U-joint repair

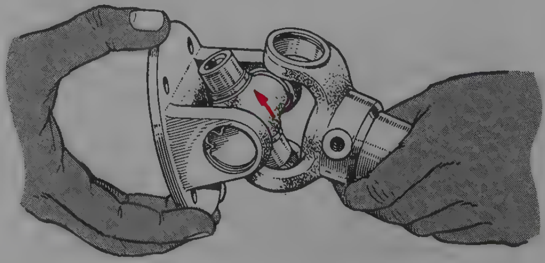


Fig. 29-28. Tip cross and remove from yoke.

kit will be needed. If the trunnions look good, clean the cross thoroughly. Blow out grease passages. Check condition of lug holes.

Wash the rollers and needles. Blow dry. If the inside of the rollers and the trunnion bearing surface is free of corrosion and grooving, the parts may be reused. Check all needles for signs of chipping or breakage. Try rollers on trunnions for evidence of looseness.

Remember: a universal joint repair kit is relatively inexpensive. If the old joint shows the slightest sign of wear, install a repair kit. If either the rollers or the cross is worn, replace both. Never install new rollers on an old cross or vice versa.

ASSEMBLING CROSS AND ROLLER UNIVERSAL JOINT

If new seal retainers are needed, drive them into place with a punch designed for the purpose. The retainer must be driven on the cross with the open side of the retainer facing outward toward the end of the trunnion. Make certain retainers are on squarely and to the full depth. See Fig. 29-29.

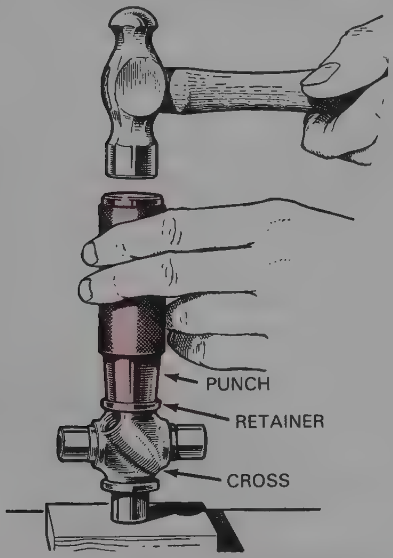


Fig. 29-29. Using special hollow punch to seat new cross seal retainer. (British-Leyland)

Pack the roller bearings with the recommended lubricant (multi-purpose universal joint grease, semifluid, or SAE 140). If the bearing is of the sealed type (no provision for greasing following installation), pack the grease reservoirs at the ends of the trunnions. Pack carefully to eliminate trapped air. Install seals.

Start one of the rollers in a yoke lug. Insert from bottom with open side of roller up to prevent loss of needles. Make sure that each roller contains the specified number of needles.

Insert one of the cross trunnions into the roller. Start the other roller making certain it slips over the trunnion, Fig. 29-30.

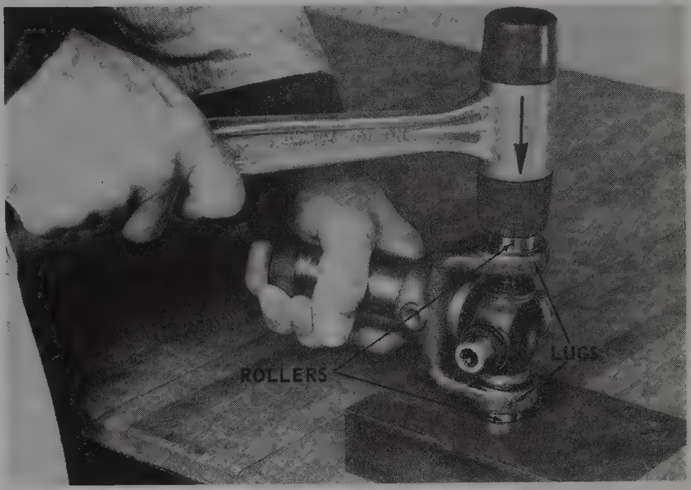


Fig. 29-30. Starting rollers into lugs. Rollers must slip over cross trunnions. (Dana Corp.)

When partially seated, place the two rollers between the vise jaws. Squeeze until FLUSH with the yoke. Stop when flush; do not overtighten. Refer to Fig. 29-31.

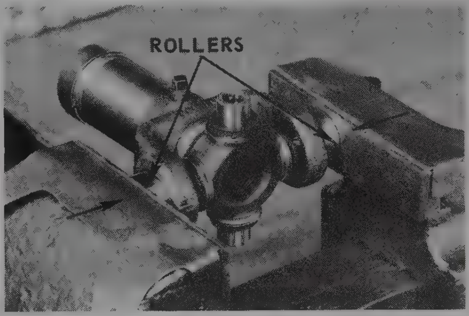


Fig. 29-31. Using vise to force rollers inward until flush with yoke lug surface. Do not tighten beyond this point.

Tap one of the rollers. Use a soft faced punch that is the full width of the roller. Tap in until it is SLIGHTLY below the snap ring groove in the lug. In the event of an inner side snap ring arrangement, tap through the lug until the snap ring can be inserted. Insert the snap ring. Use new snap rings. Make certain snap ring is seated to full depth, Fig. 29-32.

Some joints require measuring snap ring-to-yoke groove clearance to be sure fit is correct. After assembling the universal joint and installing snap rings, place joint in a vise. See Fig. 29-33. Force the cross to one side. With a feeler gauge, measure ring-to-yoke groove distance as shown in Fig. 29-34. If the measurement is not within manufacturer's specs, replace snap rings

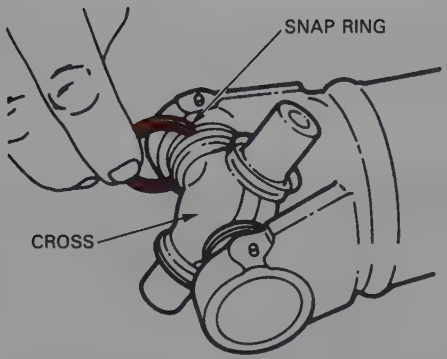


Fig. 29-32. Inserting snap ring into roller groove. (Chevrolet)

with thinner or thicker ones until recommended clearance is obtained. Try to use snap rings that are ALL the same thickness for proper propeller shaft balance.

CAUTION! Using an excessive amount of grease when rebuilding a U-joint can prevent rollers from seating fully. This will give you a false snap ring fit reading. Look at Figs. 29-33 and 29-34.

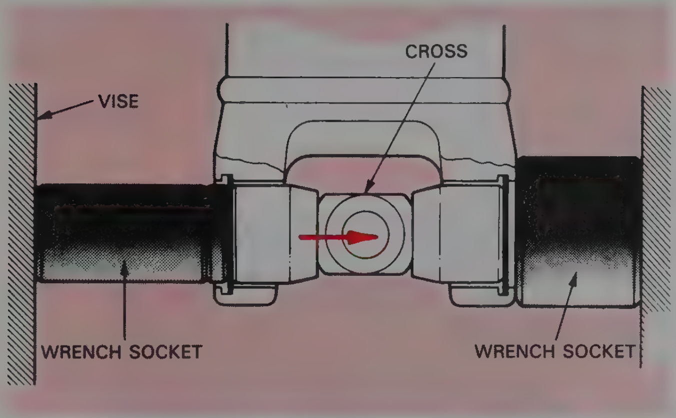


Fig. 29-33. Forcing cross to one side with a vise so that snap ring clearance can be measured. (Chrysler)

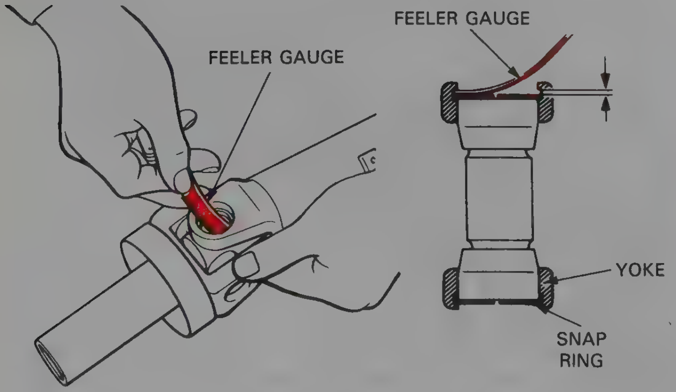


Fig. 29-34. Measuring snap ring-to-groove clearance with a feeler gauge. Note how gauge is inserted between top of snap ring and groove. (Chrysler)

Support the cross and strike the yoke to force the roller into firm contact with the snap ring. With an inner snap ring, this will force the snap ring against the inner face of the yoke. Always seat the roller in this fashion to prevent improper centering of the cross. Refer to Fig. 29-35.

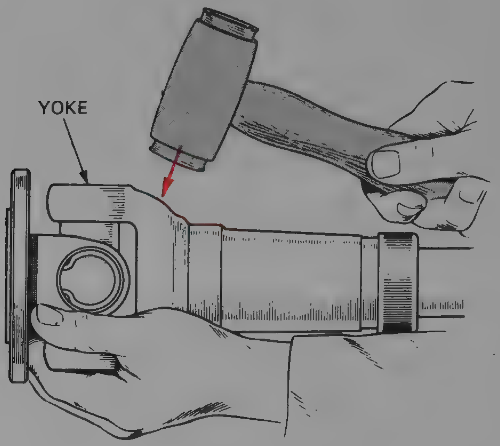


Fig. 29-35. Striking yoke to seat roller snugly against snap ring. (British-Leyland)

Install the other snap ring or rings and seat rollers against rings.

If a grease fitting is used, force universal joint grease into the joint SLOWLY until it starts to show at the seals. Use a low pressure hand grease gun or a power gun equipped with a pressure relief valve. Never use a high pressure gun without this adapter as it is possible to blow the rollers out of the yokes with the tremendous pressure. Seals may be damaged too, Fig. 29-36.

Test the action of the assembled joint. It should move throughout its range without binding. If a slight bind exists, rap the yoke lugs with a soft hammer. This will usually free the joint. If it does not, disassemble and check for source of bind.

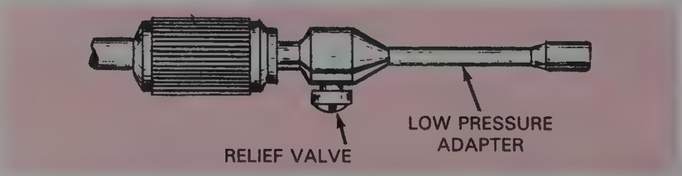


Fig. 29-36. Use low pressure adapter such as this, between high pressure grease gun and U-joint grease fitting. This will prevent joint and seal damage.

DO NOT DAMAGE PROPELLER SHAFT OR YOKE

When clamping in the vise, clamp the solid portion of the U-joint. If the yoke must be clamped, clamp lightly.

CAUTION! Avoid clamping the tube portion of the propeller shaft. All propeller shafts (aluminum, composite, or steel) are thin and can be easily damaged. This damage can cause shaft failure during operation. Support the propeller shaft according to manufacturer's recommendations.

REPAIRING CONSTANT VELOCITY UNIVERSAL JOINT

The constant velocity U-joint is literally two cross and roller joints attached by a center yoke. As such, the repair is as described for the cross and roller joint.

Mark the center yoke, slip yoke, and shaft yoke so that all parts are reassembled in the same order. Mark crosses if they will be reused so that grease fittings will be accessible, Fig. 29-37.

Remove the snap rings and force the rollers from one end. A, Fig. 29-38 shows how a special roller remover is used to force the rollers partially from the yoke.

The roller is then grasped in the vise and the center yoke is driven upward B, to complete pulling of the roller. In C, the rollers (bearing cup) are lifted from the center socket yoke. The cross (spider) is tipped and removed.

The tool is then used to force out the rollers in the other end of the center yoke, D and E, Fig. 29-38. Avoid forcing the center yoke too far to one side. Stop when the slinger ring just touches, D, Fig. 29-38. Grasp the rollers as in B and remove. F shows the constant velocity U-joint following disassembly, Fig. 29-38.

Reassemble in the reverse order of disassembly. Use new parts where required. Lubricate centering device. When assembled, remove grease plugs, lubricate, and replace plugs. If of the sealed type, lubricate before assembly, Fig. 29-39.

REPAIRING BALL AND TRUNNION UNIVERSAL JOINT

A typical ball and trunnion U-joint is pictured in Fig. 29-11.

Place the shaft in the vise. Do not tighten on hollow tube. Support free end.

Remove the dust boot or cover clamps and cut off the old boot, A, Fig. 29-40. Use a screwdriver and pry up the cover holding tabs, B, Fig. 29-40. Hold cover.

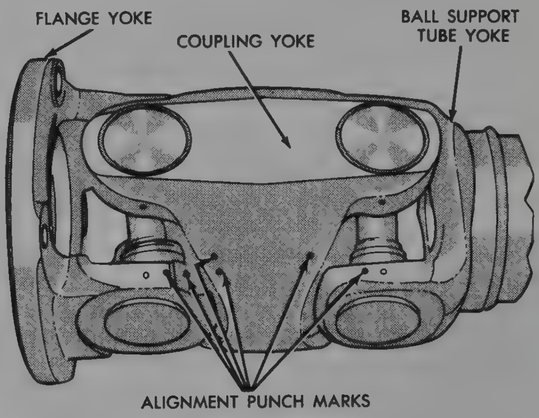

FLANGE YOKE
COUPLING YOKE
BALL SUPPORT TUBE YOKE
ALIGNMENT PUNCH MARKS

Fig. 29-37. Constant velocity joint marked before disassembly. Note double marks on left side. This prevents mixing ends. (Chrysler)

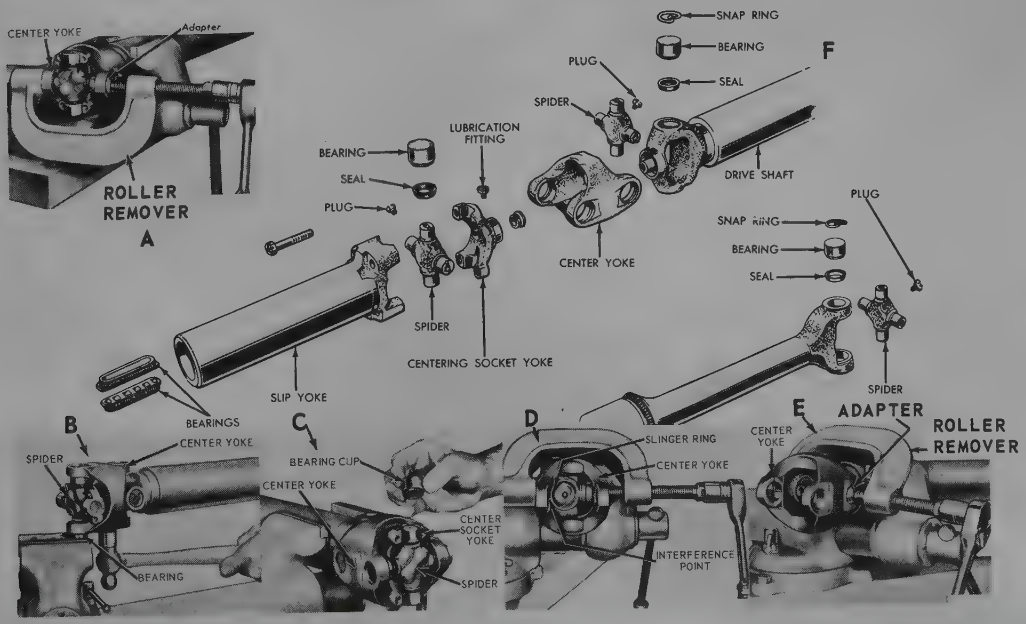

CENTER YOKE
Adapter
ROLLER REMOVER
A
SNAP RING
BEARING
SEAL
F
PLUG
SPIDER
LUBRICATION FITTING
BEARING
SEAL
PLUG
DRIVE SHAFT
PLUG
SNAP RING
BEARING
SEAL
CENTER YOKE
SPIDER
CENTERING SOCKET YOKE
SLIP YOKE
BEARINGS
SPIDER
B
SPIDER
CENTER YOKE
BEARING
C
BEARING CUP
CENTER YOKE
CENTER SOCKET YOKE
SPIDER
D
SLINGER RING
CENTER YOKE
INTERFERENCE POINT
E
CENTER YOKE
ADAPTER
ROLLER REMOVER

Fig. 29-38. Constant velocity U-joint and steps involved in disassembly. (Lincoln)

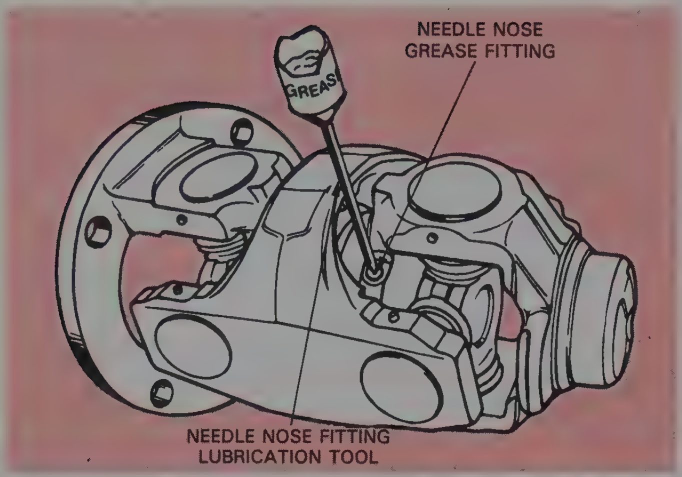

NEEDLE NOSE GREASE FITTING
GREASE
NEEDLE NOSE FITTING LUBRICATION TOOL

Fig. 29-39. Lubricating a constant velocity U-joint. Note needle nose grease fitting. (G.M.C.)

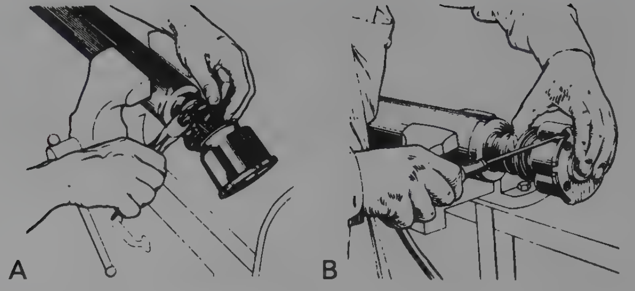


Fig. 29-40. Disassembly of ball and trunnion U-joint. A—Remove clamps and cut off boot. B—Pry up holding tabs. (Chek—Chart)

Pull cover off, A, Fig. 29-41. Remove ball and rollers, washers, springs, and buttons, B, Fig. 29-41.

Clean all parts and examine for wear. If the trunnion pin or body raceways are worn, both should be

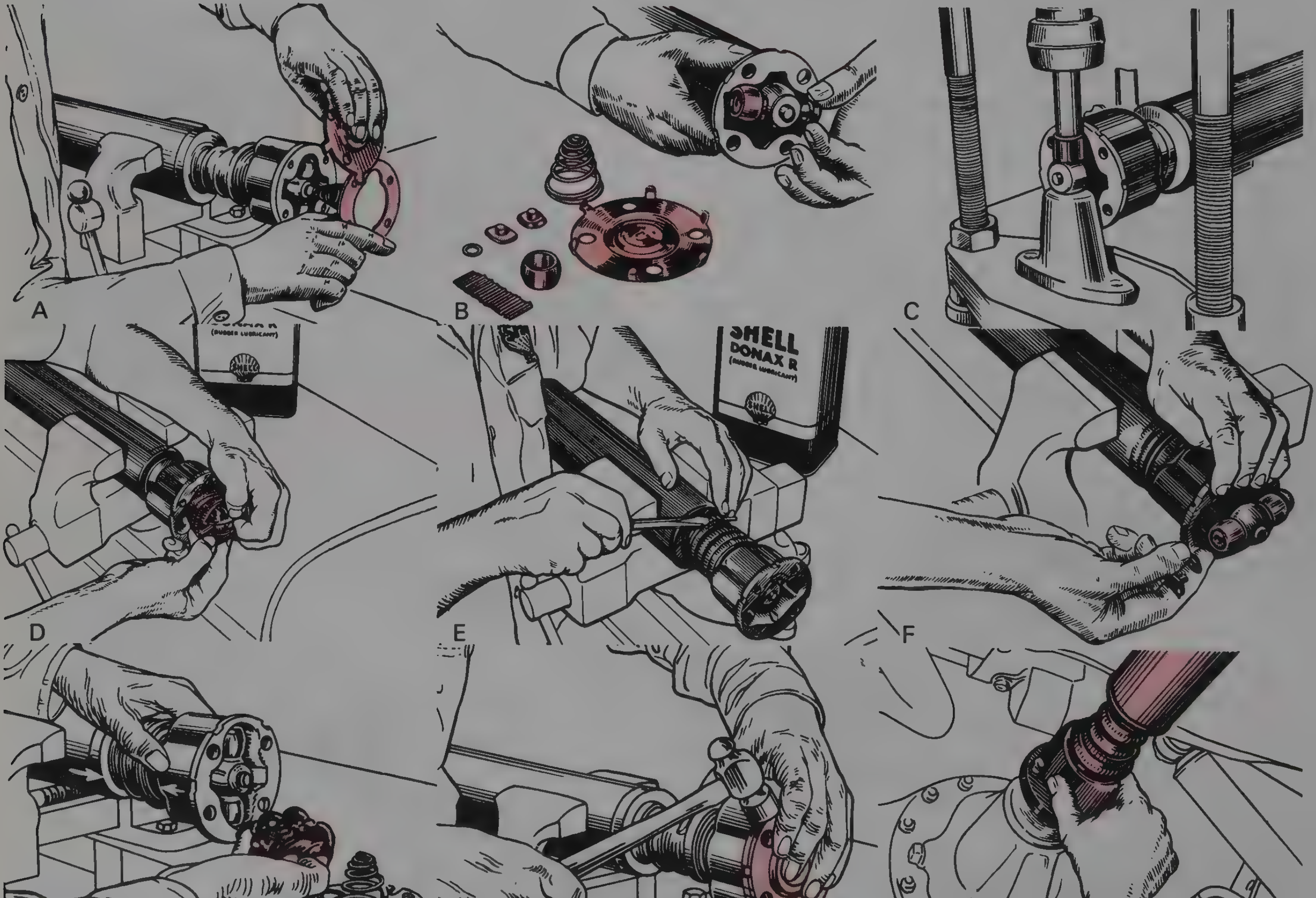

A
B
C
SHELL DONAX R (RUBBER LUBRICANT)
D
E
F
G
H
I

Fig. 29-41. Steps involved in repair of ball and trunnion universal joint. A—Remove cover. B—Remove parts. C—Install new pin. D—Work boot over pin and through body. E—Clamp boot into position. F—Install parts. G—Apply grease. H—Install cover. I—Install in car.

replaced. When a new trunnion pin is installed, C, Fig. 29-41, use a special jig so the pin protrudes an equal amount (within .003 in. or 0.08 mm) on both sides.

Lubricate new dust boot inside and out with universal joint grease or rubber lubricant. Stretch boot over trunnion pin (if pin is to be removed, install new boot before pressing new pin into position) and work it back through body. See D, Fig. 29-41. When the boot passes through the body, grasp it and work it completely free. Pull each end up on the seat area and install clamps, E. Do not use tools to force the boot into position. To do so could puncture it. If a breather is used, make sure it is properly positioned.

Lubricate the washers, ball and rollers, button, etc., with universal joint grease and install, F. Pull the body away from the trunnion pin and apply about one ounce of universal joint grease to the body raceways in back of the pin. Pull the body forward over the pin and apply one ounce of grease to the raceways. This puts grease both in front and in back of the pin, G. Do not place a supply of grease inside the boot.

Using a new gasket, place the grease cover in position and lock by bending the tabs into place, H. Fig. 29-41, I, shows the joint in position on the car.

PROPELLER SHAFT INSTALLATION

Check joints to make sure all marks are aligned. Cover slip yoke with cardboard or rags.

Position shaft in car. Support shaft during installation to prevent damage to U-joints.

Remove covering from slip yoke and lubricate outside surface as recommended. Some installations use grease; others use transmission fluid. The inner splined surface may be lubricated by transmission fluid. The unit may also require grease as in Fig. 29-42. The oil seal on the output shaft prevents automatic transmission fluid from entering the splines. This type of joint must be greased.

When connecting the U-joint, make certain that the marks on the shaft yoke and flange yoke are aligned. Check flange for nicks or burrs.

In cases where a propeller shaft has a splined stub, make certain the arrows (factory balance marks) or punch marks on the shaft and slip yoke are aligned, Fig. 29-43.

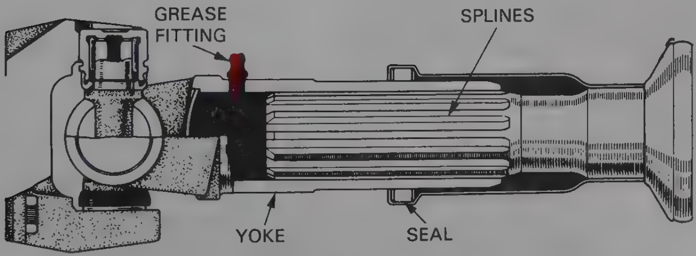


Fig. 29-42. This slip yoke setup requires greasing inner spline surface. Note grease fitting. (Toyota)

If U-bolts are used to connect rollers to the flange yoke, torque U-bolt nuts as specified. Excessive tightening will distort rollers and cause shaft shudder and short life.

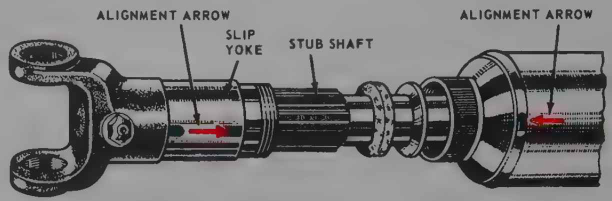


Fig. 29-43. Align marks (arrows, punch marks, etc.) when engaging splined stub shaft with slip yoke. (British-Leyland)

Before tightening U-bolts, make certain the roller heads are underneath the locating tang. Following torquing, rap joint with a soft hammer and retorque fasteners, Fig. 29-44. If a strap is used on the cross, make certain it fits into the pockets provided in the yoke, Fig. 29-45.

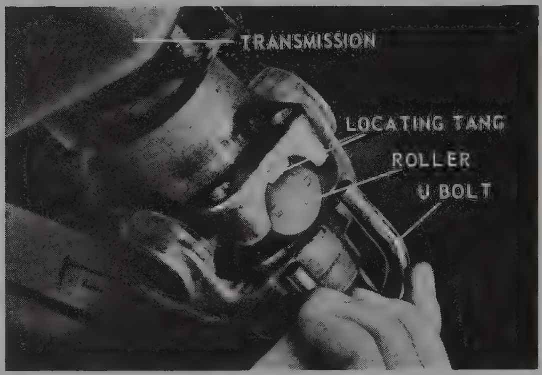


Fig. 29-44. Connecting universal joint. Note how roller fits under locating tang. (Spicer)

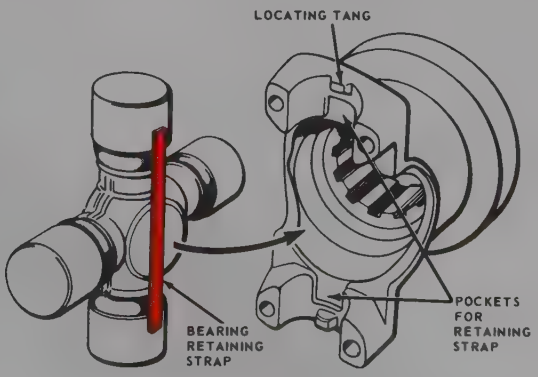


Fig. 29-45. Retaining strap, when used, must fit into yoke pockets. (Ford)

When wing type rollers are employed, secure fasteners with locking tabs.

Inspect drive line to make sure all fasteners are secured. If a center support bearing is used, torque mounting fasteners. Where specified, check clearance between end of transmission extension housing and front slip yoke face. Grasp shaft and shake sideways. There should be no discernable movement. Road test to check for quiet operation.

PROPELLER SHAFT BALANCE

The propeller shaft turns at engine rpm in high gear. This requires that the shaft be accurately balanced. If the shaft is sprung or even badly dented, it should be replaced. Proper straightening and balance is beyond the facilities of a regular garage.

If the car is being undercoated, keep the shaft and U-joints covered. Undercoating on the shaft may cause serious vibration.

The shaft may be checked for runout in the car by using a dial indicator. Mount the indicator to some rigid spot and place the stem on the drive line near one end. Turn a back wheel to rotate propeller shaft. Note reading. Move indicator to other end and then to the center.

When noting indicator reading, do not count sudden changes from a weld, flat spot, or minor tube out-of-roundness. Fig. 29-46 illustrates typical measuring points on one and two-piece drive lines. TIR (total indicator reading) at these points should generally not exceed .030 in. (0.76 mm). Follow manufacturer's recommendations for your particular drive line.

Minor shaft unbalance can occasionally be corrected by using hose clamps (Whittek type). The clamps are attached to the shaft and rotated around until the shaft is balanced. See Fig. 29-47.

If everything checks out all right, but vibration persists, disconnect the rear U-joint. Turn the pinion flange 180 deg. and reconnect. If still present, disconnect front slip yoke. Rotate yoke 180 deg. and reconnect.

PROPELLER SHAFT DRIVE ANGLE

Universal joints, when forced to operate at an angle other than that specified, may cause vibration.

When shaft vibration is present, it is advisable to check the angle formed between the centerline of the propeller shaft and the differential pinion shaft.

A special gauge is pictured in Fig. 29-48. The gauge is placed on front universal joint and propeller shaft. Pointer indicates shaft-to-joint angle. The vehicle must be level and at normal curb weight (no passengers or luggage, gas tank full). Use a drive on or axle engagement type lift. Do not use a frame contact lift as this will allow the axle housing to hang down and alter the drive angle. The gauge can also be used to check the rear universal joint angle. Note the gauge is attached to the yokes and not the crosses.

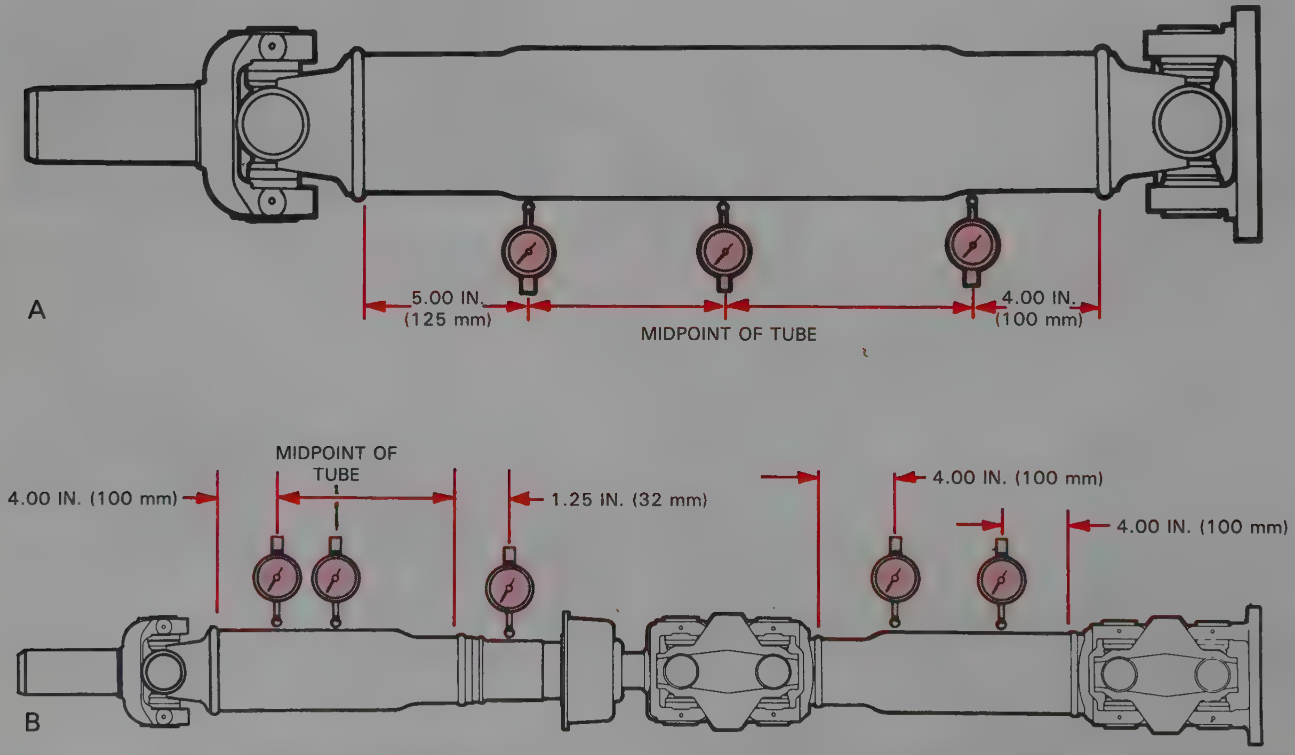


Fig. 29-46. Check points to be used for obtaining runout. A—One-piece drive line. B—Two-piece drive line. (Cadillac)

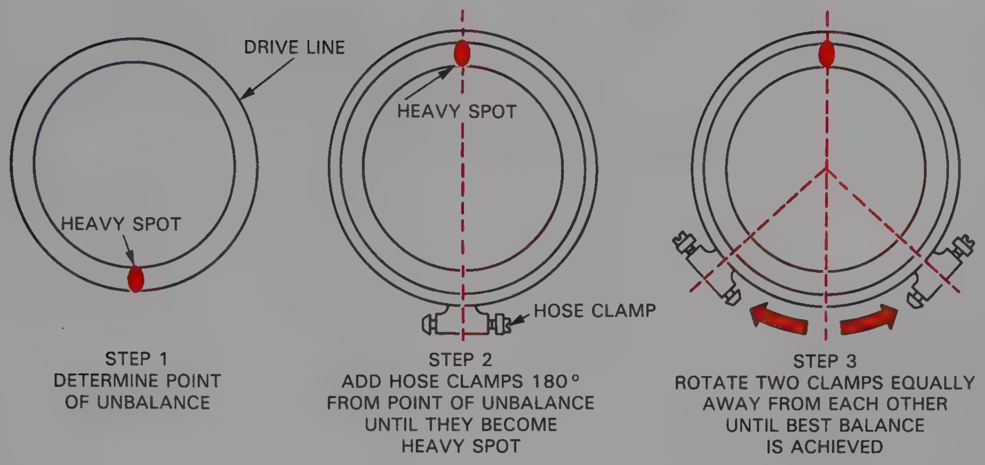

DRIVE LINE
HEAVY SPOT
HEAVY SPOT
HOSE CLAMP
STEP 1
DETERMINE POINT
OF UNBALANCE
STEP 2
ADD HOSE CLAMPS 180°
FROM POINT OF UNBALANCE
UNTIL THEY BECOME
HEAVY SPOT
STEP 3
ROTATE TWO CLAMPS EQUALLY
AWAY FROM EACH OTHER
UNTIL BEST BALANCE
IS ACHIEVED

Fig. 29-47. Eliminating drive line unbalance with Whittek type hose clamps. (Buick)

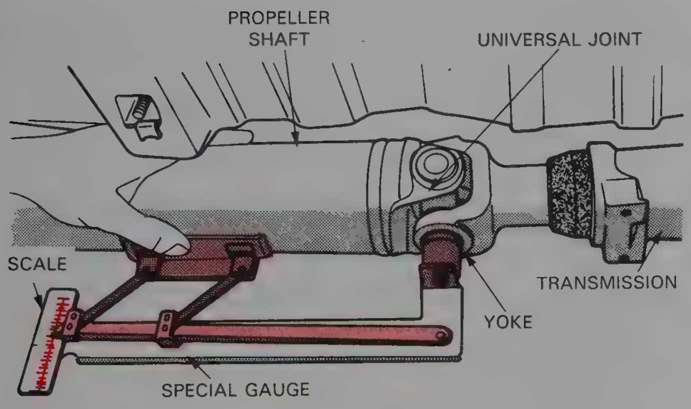

PROPELLER
SHAFT
UNIVERSAL JOINT
SCALE
TRANSMISSION
YOKE
SPECIAL GAUGE

Fig. 29-48. Using special gauge to measure front universal joint angle. Keep gauge firmly in position while measuring. (Plymouth)

A spirit level gauge can also be used to check the propeller shaft drive angle. The gauge is adjusted by centering the level bubble while holding it on the differential carrier housing, Fig. 29-49. The gauge is then held against the propeller shaft and bubble position

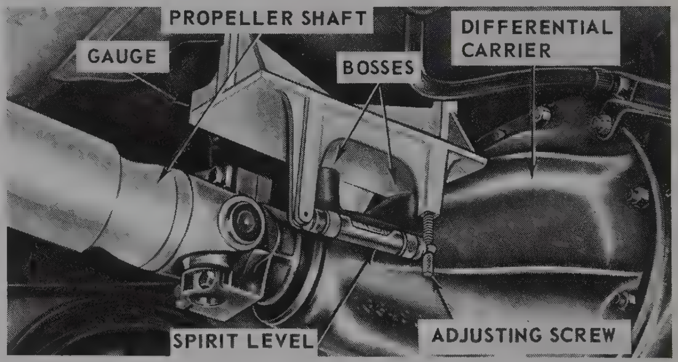

PROPELLER SHAFT
DIFFERENTIAL
CARRIER
GAUGE
BOSSES
SPIRIT LEVEL
ADJUSTING SCREW

Fig. 29-49. Adjusting spirit level to center bubble. Note how gauge is resting on carrier bosses. (Plymouth)

is checked against specifications. If reading is not within recommended range, the propeller shaft drive angle must be adjusted.

A third technique for checking drive angle is illustrated in Fig. 29-50. A long steel cable is stretched beneath the drive train. The distance from the slip yoke and the drive pinion companion flange to the wire is

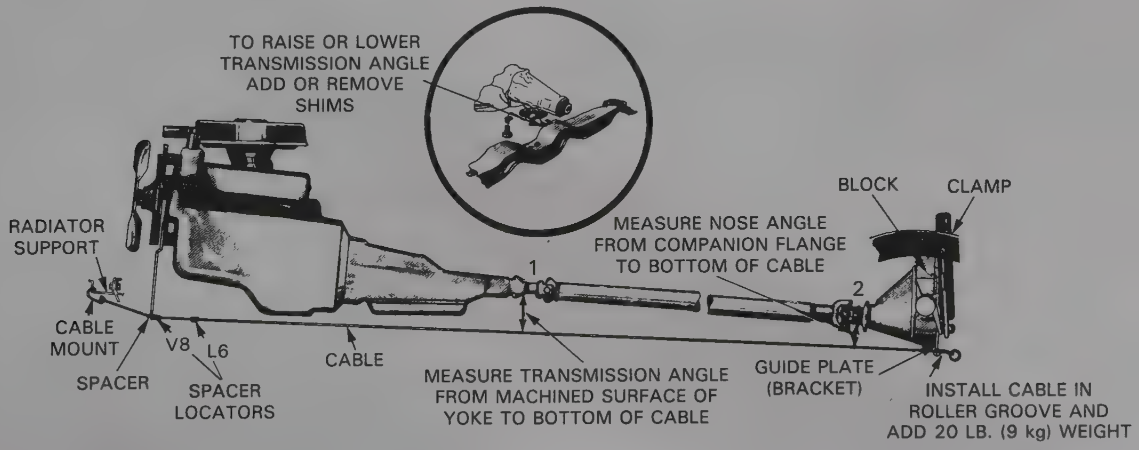

TO RAISE OR LOWER
TRANSMISSION ANGLE
ADD OR REMOVE
SHIMS
BLOCK
CLAMP
RADIATOR
SUPPORT
MEASURE NOSE ANGLE
FROM COMPANION FLANGE
TO BOTTOM OF CABLE
1
2
CABLE
MOUNT
V8
L6
CABLE
SPACER
SPACER
LOCATORS
MEASURE TRANSMISSION ANGLE
FROM MACHINED SURFACE OF
YOKE TO BOTTOM OF CABLE
GUIDE PLATE
(BRACKET)
INSTALL CABLE IN
ROLLER GROOVE AND
ADD 20 LB. (9 kg) WEIGHT

Fig. 29-50. Using steel cable to check propeller shaft drive angles. (Oldsmobile)

measured. Measurements must be as specified. Note that the transmission extension may be raised or lowered by using shims, Fig. 29-50.

The rear axle housing may be tilted by adjusting the control arms. If the arms are of the nonadjustable type, new arms must be installed.

Where leaf rear springs are used, tapered wedges may be inserted betwen the spring and the axle spring pad.

If the thick portion of the wedge faces the rear of the car, the pinion shaft companion flange will be tilted downward. To raise the flange, insert the wedge so that the thick side faces the front. See Fig. 29-51.

The usual drive angle adjustment involves the axle housing only. Many cars do not provide for transmission mount adjustments.

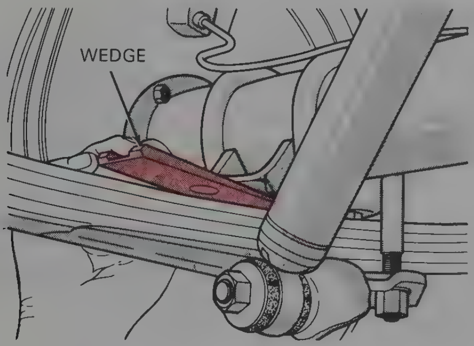


Fig. 29-51. Inserting tapered wedge between rear spring and axle housing to change propeller shaft drive angle. (Chrysler)

SUMMARY

Basic drive line types are the torque tube and Hotchkiss. The open shaft Hotchkiss type is widely used.

Propeller shafts can be made of one or more pieces.

Although the ball and trunnion universal joint is still in use, the cross and roller type is used in most applications.

The cross and roller joint consists of two yokes connected by a cross. Rollers, containing needle bearings, reduce friction.

The rollers may be retained by snap rings, U-bolts, cap screws, or other means.

The ball and trunnion U-joint does not require a slip joint as the joint allows longitudinal movement of the shaft.

When disconnecting a U-joint to remove the shaft, do not use a bar between the yoke and cross to hold against turning.

Mark shaft, joint, and drive flange to preserve balance. Yokes on both ends of the shaft must be in the same plane.

Support shaft during removal. Cover slip yoke. Avoid bending sharply at U-joint. Do not allow shaft to hang supported by a U-joint. Tape rollers to cross to prevent dropping off during shaft removal.

Never tighten vise jaws on propeller shaft tube. Support the free end of the shaft while the other rests in a vise. Use jaw covers on vise.

Remove snap rings and dismantle joint. Clean and inspect. If cross or rollers are worn, replace both. Use new seals and snap rings. Lubricate with universal joint grease. Use low pressure gun and fill joint slowly. On sealed types, lubricate before assembly.

After joint is assembled and snap rings are installed, strike yokes to seat rollers against snap rings. Joint action should be smooth.

When installing propeller shaft, cover slip yoke to prevent entry of dirt and damage from contact with car underbody parts. Support shaft. Lubricate slip yoke. Yokes must be in same plane. All marks must be aligned.

Torque joint U-bolts or cap screws. Tap joint and retorque. Avoid excessive tightening. Crimp locking tabs against cap screws.

Check all fasteners. Shake shaft to detect looseness. Road test for proper operation.

If shaft vibration is present, check shaft for runout, presence of undercoating, misaligned marks, drive angle, etc. Replace sprung or badly dented shafts.

Drive angle may be checked by using special gauges, levels, protractors, and plumb bob, etc. Car must be level and at curb weight for drive angle check. Tilt rear axle housing to provide correct drive angle by adjusting control arms (coil springs) or by using tapered wedges (leaf springs). Some cars require adjusting transmission height also. Others are nonadjustable.

PROBLEM DIAGNOSIS

PROBLEM: NOISY OPERATION

Possible Cause	Correction
1. U-joint fasteners (U-bolts, cap screws, etc.) loose.	1. Tighten fasteners.
2. Lack of lubricant.	2. Lubricate.
3. Worn U-joint.	3. Repair joint.
4. Worn center support bearing.	4. Replace bearing.
5. Loose center support.	5. Tighten support fasteners.
6. Joint or shaft striking some part of car underbody.	6. Shim, tighten, or replace center mount. Check for debris in frame tunnel.

PROBLEM: PROPELLER SHAFT VIBRATION OR SHUDDER

Possible Cause	Correction
1. U-joint fasteners loose.	1. Tighten fasteners.
2. Worn U-joint.	2. Repair joint.
3. Shaft sprung or dented.	3. Replace shaft.
4. Undercoating on shaft.	4. Remove undercoating.
5. Ball of grease in dust boot of ball and trunnion joint.	5. Disassemble joint, clean, and lubricate properly.
6. Joint flange surface nicked or burred.	6. Disassemble. File off burrs.
7. Dry slip joint.	7. Clean and lubricate.
8. Shaft yokes out of phase (not aligned).	8. Align yokes as required.
9. Shaft yoke and slip yoke assembled wrong.	9. Disconnect slip yoke. Rotate 180 deg. and connect.
10. Shaft yoke and pinion flange yoke assembled wrong.	10. Disconnect. Rotate flange yoke 180 deg. Connect.
11. Cross not centered in yoke.	11. Strike yoke to move rollers out against snap rings.
12. U-joints tight.	12. Strike yoke lugs to free. Replace joint if needed.
13. Roller U-bolts overtightened.	13. Loosen and torque properly.
14. Drive angle wrong.	14. Check and adjust as required.
15. Loose center support.	15. Tighten center support.
16. Center support rubber insulator deteriorated.	16. Replace unit.
17. Worn center support bearing.	17. Replace bearing.
18. Loose rear spring U-bolts.	18. Torque bolts.
19. Loose rear axle housing control arm bolts.	19. Tighten bolts. Replace bushings if worn.
20. Loose pinion companion flange retaining nut.	20. Tighten nut.
21. Worn slip joint splines.	21. Replace slip yoke and/or stub shaft.
22. Weak springs.	22. Replace springs.
23. Rear spring center bolt sheared — axle housing shifted.	23. Replace center bolt.

KNOW THESE TERMS

Torque tube drive, Hotchkiss drive, Drive line, Cross and roller joint, Ball and trunnion joint, Constant velocity joint, Center support bearing, U-bolt, Yoke, Roller, Cross, Centering socket, Pinion flange, Slip joint, Snap ring, Trunnion, Low pressure adapter, Needle nose fitting, Dust boot, Balance weight, Wing type roller, Yoke pocket, Spirit level, Shaft drive angle, Shaft runout, Torque arm.

QUIZ - Chapter 29

1. The two basic drive line types are the torque tube and the hotchkiss.
2. The cross and roller U-joint is the most widely used. [✓ True] or False?
3. The rollers in the cross and roller joint are retained by:
   a. Snap rings.
   b. U-bolts.
   c. Cap screws.
   [✓ d.] One or more of the above depending on design.
4. Wing type rollers are secured with snap rings. True or False?
5. The ball and trunnion joint eliminates the need for a slip joint. [✓ True] or False?
6. The constant velocity U-joint divides power even of the drive angle between each end.
7. List six important points that must be observed for proper propeller shaft removal.
8. What portion of a propeller shaft is easily damaged by clamping in a vise? Tube
9. Explain the procedure in removing cross rollers from the yoke.
10. If the cross is in good condition but the rollers are not, it is permissible to replace the roller only. True or [✓ False]?
11. Following installation of the U-joint snap rings, strike the Yokes to seat the Roller against the snap rings.
12. High pressure grease guns require the use of a low pressure relief valve to prevent damage to the U-joint.
13. Some U-joints are sealed and must be lubricated before assembly. [✓ True] or False?
14. A newly assembled U-joint should have a rather stiff action until broken in. True or [✓ False]?
15. When lubricating a ball and trunnion joint, place the lubricant inside:
    [✓ a.] The body raceways.
    b. The dust boot.
    c. No lubricant needed.
16. The yokes on each end of the propeller shaft should be in the same plane.
17. Before removing a propeller shaft, it is important that the shaft and pinion flange or yoke be Mark to preserve shaft balance.
18. Roller U-bolts, if tightened excessively, can cause vibration and rapid worn.
19. List four things that can cause propeller shaft vibration. Shaf runout, Misaling, drive angle
20. The drive angle can be altered by adjusting the control arms on cars with coil springs.
21. Lubricate U-joints with engine oil. True or [✓ False]?

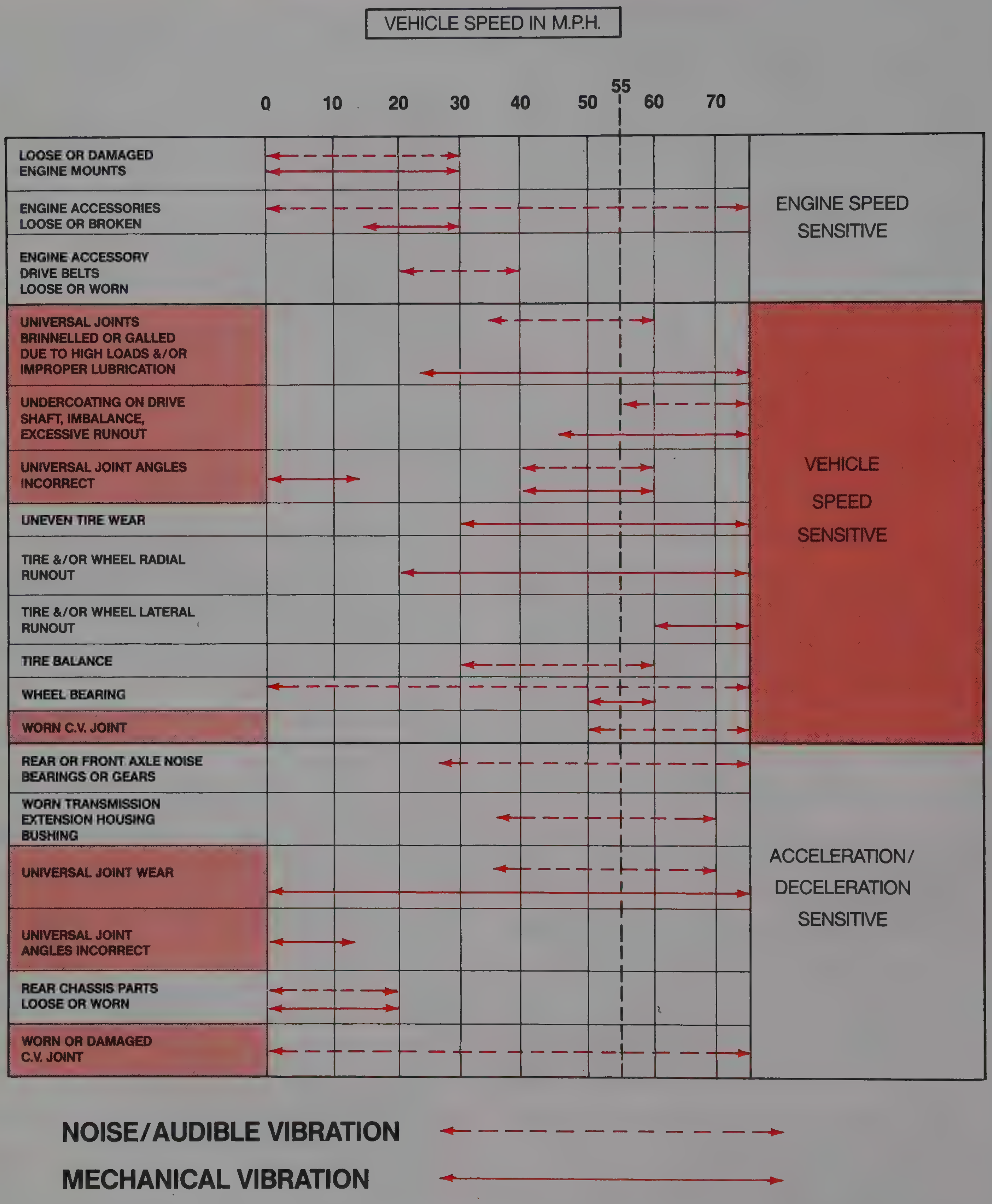
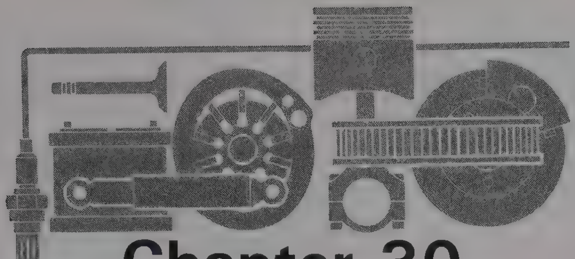


Chart indicates the most common causes of vibration related to vehicle speed. (Perfect Circle)



Chapter 30

DIFFERENTIAL, AXLE, SEAL, HOUSING SERVICE

After studying this chapter, you will be able to:

☐ Explain the construction, operation, and service of axle housings.

☐ Compare drive axle types.

☐ Describe the construction, operation, and service of differentials.

☐ Explain the construction, operation, and service of front-wheel drive axles.

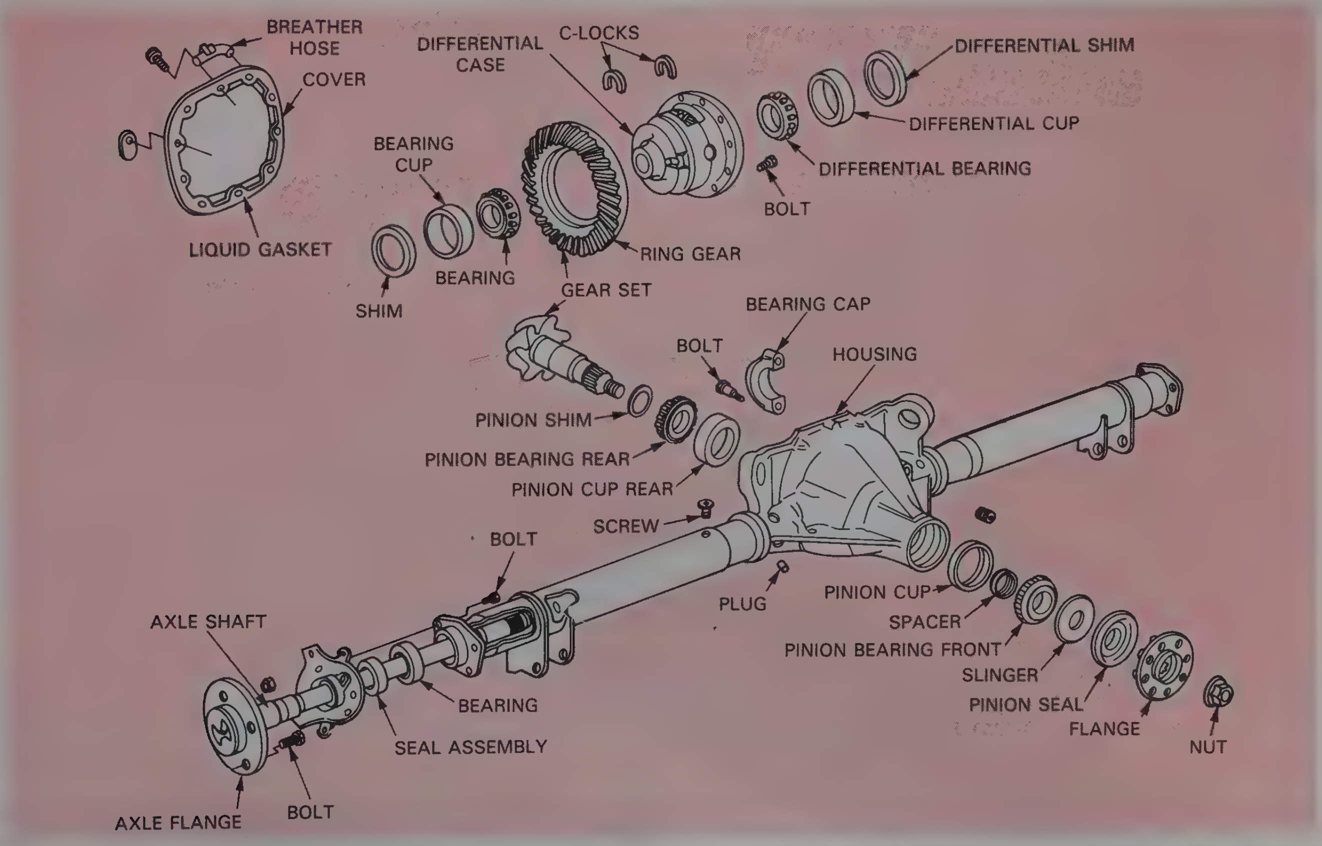
☐ Diagnose differential and axle problems.

The typical automotive drive axle assembly is of the semifloating design in which the axle drives, retains, and supports the wheel. A single ball or roller wheel bearing is used at the outer end of each axle housing.

The axle may be retained in the housing by a retainer plate or by axle shaft locks on inner ends of the axles. See Fig. 30-1, 30-2, and 30-3.

The differential carrier may be of the integral type (permanent part of the axle housing), Fig. 30-1. It may also be a removable type, Fig. 30-3.

An exploded view of one type independent front axle assembly for a four-wheel drive vehicle is shown in Fig.



BREATHER HOSE
COVER
DIFFERENTIAL CASE
C-LOCKS
DIFFERENTIAL SHIM
DIFFERENTIAL CUP
DIFFERENTIAL BEARING
BEARING CUP
BOLT
LIQUID GASKET
RING GEAR
BEARING
SHIM
GEAR SET
BEARING CAP
BOLT
HOUSING
PINION SHIM
PINION BEARING REAR
PINION CUP REAR
SCREW
BOLT
PLUG
PINION CUP
SPACER
PINION BEARING FRONT
SLINGER
PINION SEAL
FLANGE
NUT
AXLE SHAFT
BEARING
SEAL ASSEMBLY
AXLE FLANGE
BOLT

Fig. 30-1. Exploded view of a rear drive axle assembly. Study the different parts and relationships. (Ford)

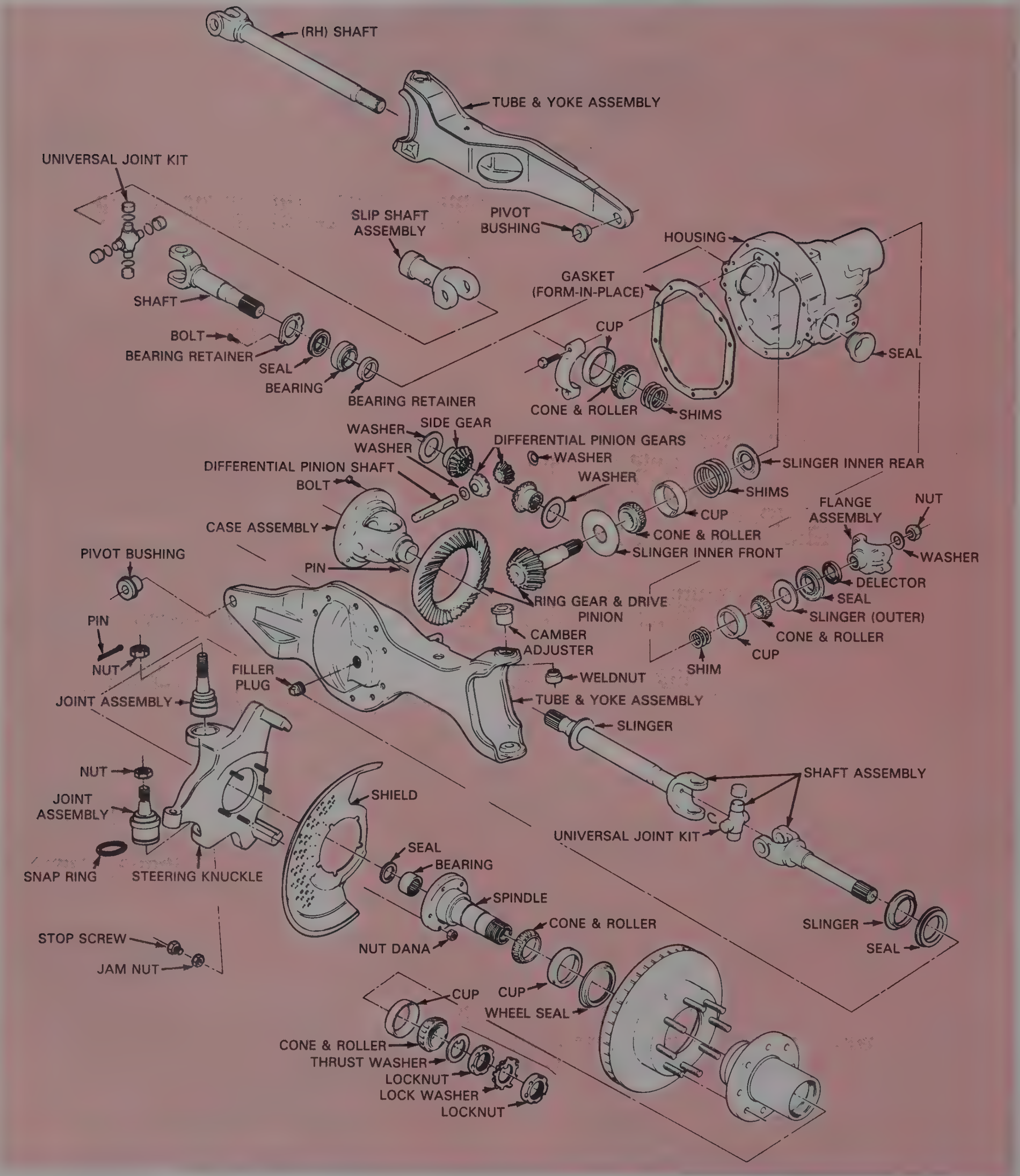

(RH) SHAFT
TUBE & YOKE ASSEMBLY
UNIVERSAL JOINT KIT
SLIP SHAFT ASSEMBLY
PIVOT BUSHING
HOUSING
GASKET (FORM-IN-PLACE)
SHAFT
BOLT
BEARING RETAINER
SEAL
BEARING
BEARING RETAINER
CUP
SEAL
CONE & ROLLER
SHIMS
WASHER
SIDE GEAR
WASHER
DIFFERENTIAL PINION GEARS
WASHER
WASHER
SLINGER INNER REAR
DIFFERENTIAL PINION SHAFT
BOLT
SHIMS
FLANGE ASSEMBLY
NUT
CASE ASSEMBLY
CUP
CONE & ROLLER
SLINGER INNER FRONT
WASHER
PIVOT BUSHING
PIN
DELECTOR
SEAL
RING GEAR & DRIVE PINION
SLINGER (OUTER)
CONE & ROLLER
PIN
CAMBER ADJUSTER
CUP
NUT
SHIM
FILLER PLUG
WELDNUT
JOINT ASSEMBLY
TUBE & YOKE ASSEMBLY
SLINGER
NUT
SHAFT ASSEMBLY
JOINT ASSEMBLY
SHIELD
UNIVERSAL JOINT KIT
SEAL
SNAP RING
STEERING KNUCKLE
BEARING
SPINDLE
STOP SCREW
CONE & ROLLER
SLINGER
NUT DANA
SEAL
JAM NUT
CUP
CUP
WHEEL SEAL
CONE & ROLLER
THRUST WASHER
LOCKNUT
LOCK WASHER
LOCKNUT

Fig. 30-2. An exploded view of an independent suspension, front-drive axle assembly, as used on one four-wheel drive. (Ford)

30-2. A cutaway of an assembled drive axle is pictured in Fig. 30-4. Study part names and relationships.

The differential unit used in one front wheel drive car is of a planetary gear design. This permits regular differential action while allowing a narrow, space-saving design.

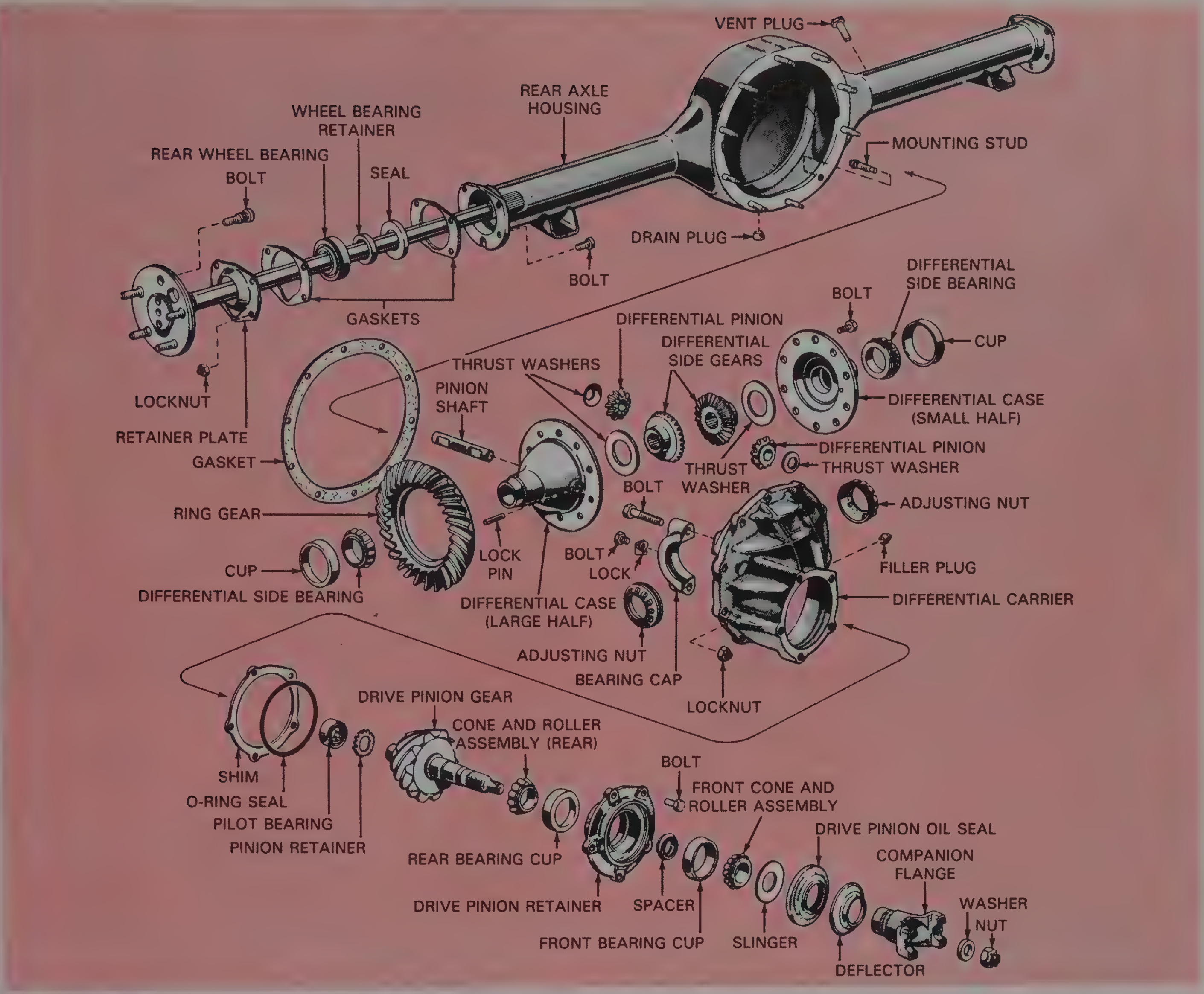

VENT PLUG
REAR AXLE HOUSING
WHEEL BEARING RETAINER
MOUNTING STUD
REAR WHEEL BEARING
BOLT
SEAL
DRAIN PLUG
BOLT
DIFFERENTIAL SIDE BEARING
GASKETS
BOLT
DIFFERENTIAL PINION
CUP
DIFFERENTIAL SIDE GEARS
THRUST WASHERS
PINION SHAFT
LOCKNUT
DIFFERENTIAL CASE (SMALL HALF)
RETAINER PLATE
DIFFERENTIAL PINION
GASKET
THRUST WASHER
THRUST WASHER
BOLT
ADJUSTING NUT
RING GEAR
LOCK PIN
BOLT
LOCK
FILLER PLUG
CUP
DIFFERENTIAL SIDE BEARING
DIFFERENTIAL CASE (LARGE HALF)
DIFFERENTIAL CARRIER
ADJUSTING NUT
BEARING CAP
LOCKNUT
DRIVE PINION GEAR
CONE AND ROLLER ASSEMBLY (REAR)
BOLT
FRONT CONE AND ROLLER ASSEMBLY
SHIM
O-RING SEAL
PILOT BEARING
PINION RETAINER
DRIVE PINION OIL SEAL
REAR BEARING CUP
COMPANION FLANGE
DRIVE PINION RETAINER
SPACER
WASHER
NUT
FRONT BEARING CUP
SLINGER
DEFLECTOR

Fig. 30-3. Drive axle assembly with removable differential carrier. (Ford)

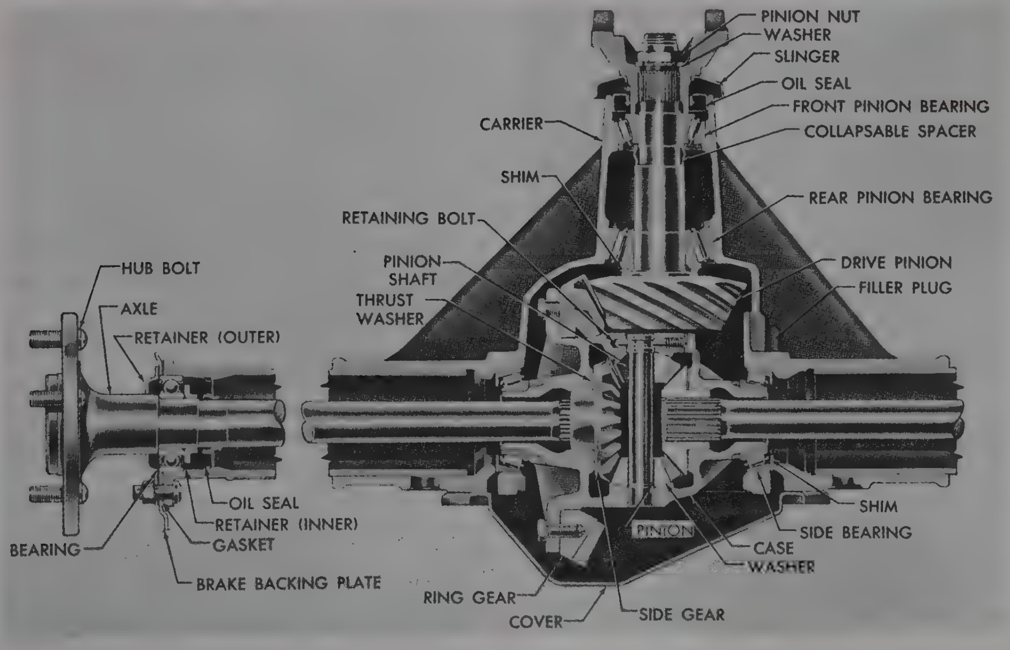

PINION NUT
WASHER
SLINGER
OIL SEAL
FRONT PINION BEARING
CARRIER
COLLAPSABLE SPACER
SHIM
REAR PINION BEARING
RETAINING BOLT
HUB BOLT
PINION SHAFT
DRIVE PINION
FILLER PLUG
THRUST WASHER
AXLE
RETAINER (OUTER)
OIL SEAL
RETAINER (INNER)
GASKET
BEARING
BRAKE BACKING PLATE
PINION
SHIM
SIDE BEARING
CASE
WASHER
RING GEAR
COVER
SIDE GEAR

Fig. 30-4. Drive axle — assembled view. (Oldsmobile)

ROAD TESTING

Before road testing for drive axle assembly problems, check the lubricant level. Add lubricant if required.

Check the tires for a saw-tooth wear pattern or for a mud and snow tread design. Both can produce distinct rumbles, growls, or other noises. Bring the tire pressure to specifications.

Drive the car far enough to warm the lubricant. Then check action during DRIVE (acceleration), CRUISE (engine driving enough to maintain car speed), FLOAT (engine neither driving nor holding back—car speed will slowly decrease), COAST (accelerator released, engine on compression).

NOISES OFTEN MISTAKEN FOR DRIVE AXLE SOUNDS

If the tires are suspected, inflate both front and back tires to 50 psi (345 kPa). If the tires are responsible, the noise should be noticeably altered. Reduce pressure to recommended level following road test.

Worn or improperly adjusted front wheel bearings can produce sounds similar to those caused by a defective rear axle. Raise the front end and shake wheel to detect looseness. Spin to test for roughness. During the road test, noise produced by the front wheel bearings can usually be reduced or altered by pressing on the brake while maintaining car speed.

Certain road surfaces produce distinct sounds. By driving on a different surface, these sounds can be quickly identified.

The transmission can also produce noises easily confused with typical drive axle problems.

The engine is occasionally the source of rear axle sounds. Operate the engine, car standing still, at the approximate rpm at which the sound was noticed during the road test. If the sound is again heard, it will obviously not be the drive axle.

Check propeller shaft for possible unbalance or wear.

When road testing, sounds produced by tires, front wheel bearings, road surface, or propeller shaft unbalance will not change when car is switched from DRIVE to COAST (or vice versa).

RELATING DRIVE AXLE SOUNDS TO SPECIFIC PARTS

Bearing sounds tend to produce a low-pitched whine or growl that is fairly constant in pitch and extends over a wide range of road speed.

Sounds produced by gears are apt to be of variable pitch and most pronounced in specific speed ranges or pull (drive, cruise, float, coast) conditions.

Defective rear wheel bearings will produce a continuous growl that is insensitive to pull conditions. Sudden turns to the right or left, in that this will increase or decrease the load on a given bearing will alter the sound somewhat. Jack up rear of car and turn wheels slowly while "feeling" for any signs of roughness. Chipped bearings can produce a clicking sound.

Ring and pinion noise will usually be related to a specific pull condition. If it shows during DRIVE, it will probably disappear during COAST.

Differential pinion and side gear noise will be noticeable on turns as there is little movement of these gears in straight ahead driving. Pinion bearing noise is low pitched and continuous.

When drive pinion bearings or differential case side bearings are worn, the ring and pinion backlash and tooth contact pattern is altered. This can produce a compound noise made up of bearing growl and gear whine.

A low speed squeal can be caused by the pinion oil seal.

A clanking sound occurring during acceleration or deceleration may be caused by worn universal joints, worn transmission, excessive ring and pinion backlash, worn pinion and axle side gear teeth, or worn drive pinion shaft.

REPLACING PINION SHAFT SEAL AND/OR FLANGE

Disconnect and move propeller shaft out of the way (see chapter on Propeller Shaft and Universal Joint Service).

If required, measure pinion shaft bearing preload by using an inch-pound torque wrench.

With the rear wheels free and emergency brake released, rap brake backing plates to free brake shoes from the drum. Spin each wheel several times to make certain there is no drag. One method of insuring complete freedom from brake drag is to remove both rear wheels and brake drums.

Use a torque wrench with the proper socket to turn

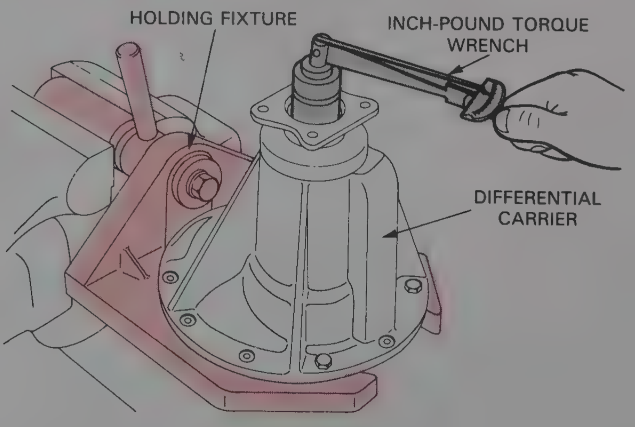


Fig. 30-5. Measuring torque required to turn pinion shaft. Note carrier holding fixture. (Chrysler)

the drive pinion shaft through several complete revolutions. Note inch-pound reading during turning. Write this down, Fig. 30-5.

SCRIBE SHAFT, NUT, AND FLANGE

Scribe a line starting on the pinion shaft end and running along the threads up to and partway across the end of the nut. Prick punch the companion flange in line with the scribe mark. Note the number of threads exposed beyond the nut. This procedure will insure correct reassembly of all parts. If a new companion flange will be installed, it will be unnecessary to scribe and punch mark.

USE A SPECIAL HOLDING TOOL

Use a pinion companion flange holding tool to keep the flange from moving while the retaining nut is removed. DO NOT TRY TO USE A PRY BAR OR LARGE CRESCENT WRENCH TO HOLD THE FLANGE. TO PREVENT DAMAGE, USE A TOOL DESIGNED FOR THE JOB, Fig. 30-6.

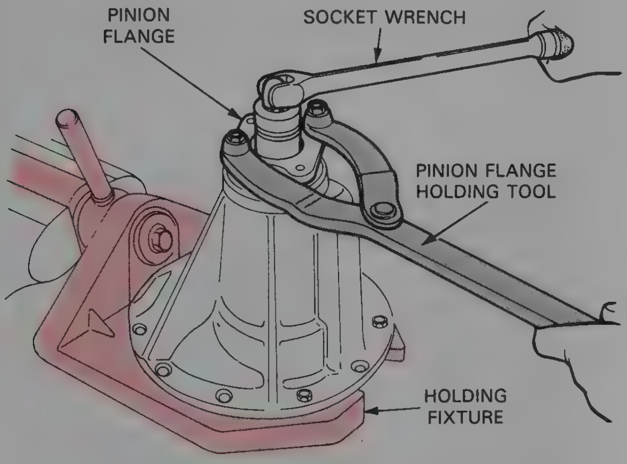


Fig. 30-6. Using a pinion flange tool to prevent flange rotation while removing retaining nut with socket wrench. (Chrysler)

Following pinion nut removal, use a pinion flange puller to remove the flange. One such puller is pictured in Fig. 30-7. DO NOT TRY TO POUND THE FLANGE OFF.

SEAL REMOVAL AND INSTALLATION

Remove pinion oil seal by prying out of the carrier or by using a threaded puller as in Fig. 30-8. Before removing, note depth to which seal is seated.

Wipe out the seal recess thoroughly. If necessary, soak new seal (leather type) in 10W engine oil for 30 minutes. Wipe off outer diameter of seal and coat with a thin layer of nonhardening sealer. Make certain new seal is of the correct size and type.

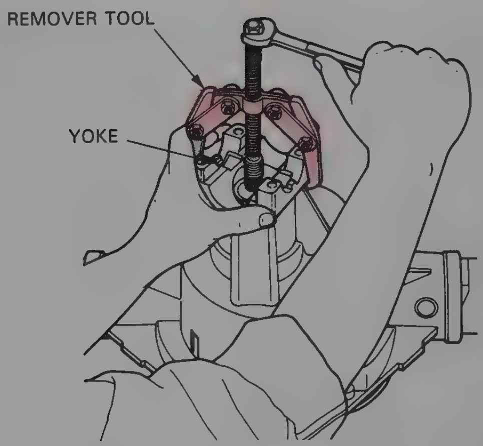


Fig. 30-7. Using a puller to remove differential pinion yoke or flange. (Ford)

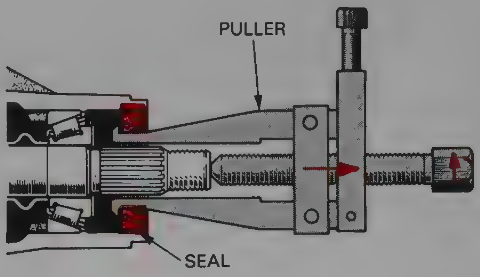


Fig. 30-8. Removing pinion oil seal with special puller. (Toyota)

With a proper seal installer, drive the seal (lip facing inward) into place. Drive on squarely and to the correct depth. Fig. 30-9 pictures the installation of a pinion seal. Although the carrier is mounted on a repair fixture, seal installation with the carrier in the car is identical.

Some manufacturers recommend installing the seal with a special installer that forces the seal into position by tightening the pinion nut. This eliminates hammering and the possibility of distorting the seal.

CHECK PINION FLANGE

If the old pinion shaft flange is to be reused, wash and blow dry. Inspect the seal contact surface. If nicked or burred, sand with No. 400 grit paper (wet type). Lubricate with kerosene while sanding. Sand around the flange so as to avoid leaving scratches across the surface. PULL THE PAPER AROUND THE SURFACE TO AVOID SANDING A FLAT SPOT. If the seal surface is worn or if the splines show evidence of wear, discard the flange.

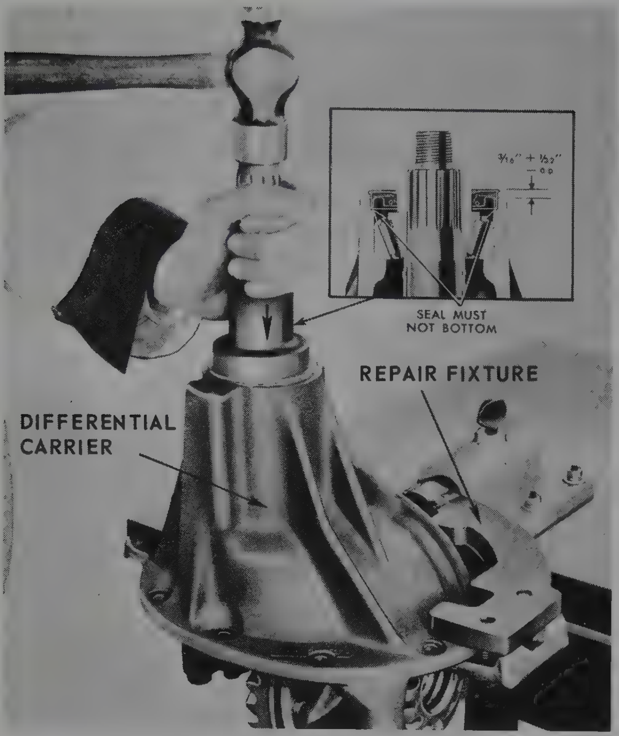


Fig. 30-9. Installing pinion oil seal. Drive in squarely to specified depth. Check manufacturer's specifications. (G.M.C.)

When a new flange will be installed, check for nicks, burrs, proper size, and shape.

INSTALL FLANGE AND ADJUST PINION BEARING PRELOAD

Lubricate seal lip, flange seal contact surface, and splines with gear oil. Align punch mark on flange with scribe mark on shaft. Start flange into place. If a new flange is used, alignment is not required. If difficulty is experienced in getting flange on far enough to start retaining nut, use a puller. Never pound on flange as it can inflict serious damage to the bearings and/or ring and pinion gear.

Install the washer and pinion shaft nut. Place a small amount of lubricant on the face of the washer and on the nut threads. Use a new nut and washer if specified.

Grasp the flange with a holding tool and tighten nut. When the nut starts to tighten the flange in place, rotate the pinion shaft a few times to make sure the bearings are seated.

When preload shims and a solid spacer are used, manufacturers may recommend tightening the pinion nut to a specified torque. Follow manufacturer's instructions. When a collapsible preload spacer is used, the directions may call for bringing the nut up to the original mark (old flange being used) plus an additional amount such as 1/8 turn or 1/32 in. (0.79 mm).

Another technique involves gradually tightening the retaining nut to a specific bearing preload. Preload is measured with an inch-pound torque wrench. It should be equal to the preload before disassembly. Check preload frequently during the tightening process to avoid exceeding recommended preload. A few additional inch-pounds may be recommended. This method will work with either a new or used flange.

If the bearing preload is exceeded on designs employing a collapsible preload spacer, a new spacer must be installed. Do not try to correct by backing off pinion nut to obtain correct preload. When preload is exceeded, the spacer is collapsed to point where ring and pinion contact pattern is disturbed.

REMEMBER: PINION BEARING PRELOAD MUST BE CORRECT. FOLLOW MANUFACTURER'S SPECIFICATIONS.

Connect universal joint. Inspect lubricant level in axle housing.

AXLE REMOVAL — FLANGED END TYPE

The flanged end axle is in common use. Refer to Figs. 30-1, 30-3, and 30-4.

To pull an axle, remove the wheel. Pull the brake drum off after unscrewing the small drum retaining cap screw or flat Tinnerman nuts threaded over the lug bolts. Look at Fig. 30-10.

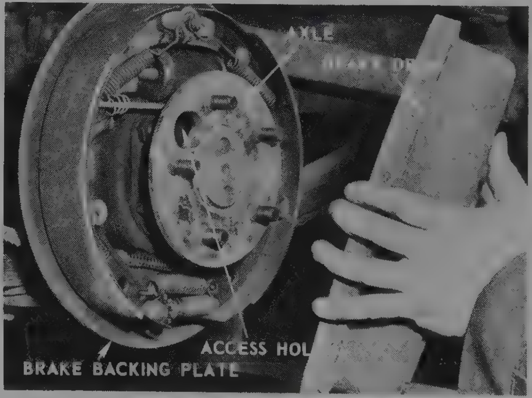


Fig. 30-10. Removing brake drum. Note access hole in axle flange for removing backing plate fasteners. (Chicago Rawhide)

Remove the nuts from the bearing retainer plate. If the design permits, pull the retainer plate outward far enough to reinstall one nut to hold the brake backing plate in place, Fig. 30-11.

Attach a slide hammer puller to the axle flange. With a few sharp blows, pull the axle bearing free of the housing. Remove tool and slide axle from housing. Refer to Fig. 30-12.

If a nut was not placed on one backing plate bolt

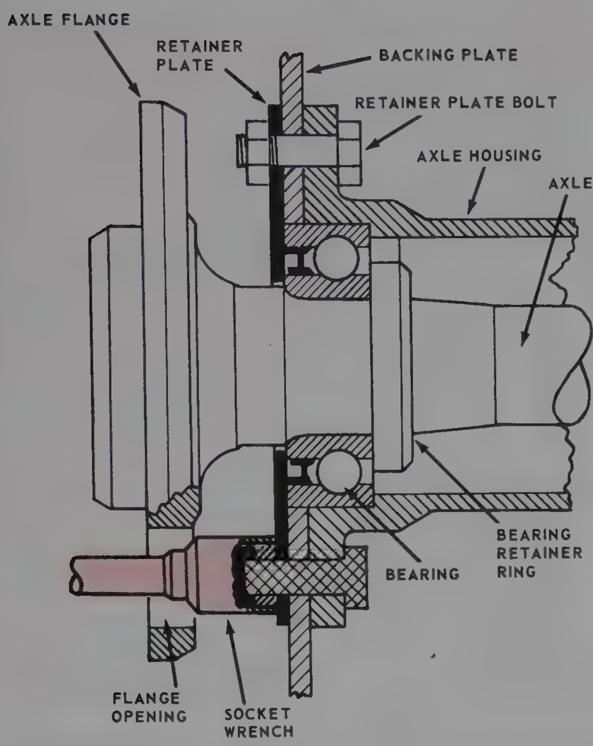


Fig. 30-11. Removing nuts from axle retainer plate bolts. Note how socket is passed through hole in axle flange.

before axle removal, make certain backing plate is not disturbed when axle is pulled. Place a nut in position as soon as the axle is out. THIS IS VERY IMPORTANT AS THE BRAKE LINE CAN BE BENT, KINKED, OR WEAKENED IF THE BACKING PLATE IS MOVED.

A typical housing end backing plate and axle assembly is illustrated in Fig. 30-13.

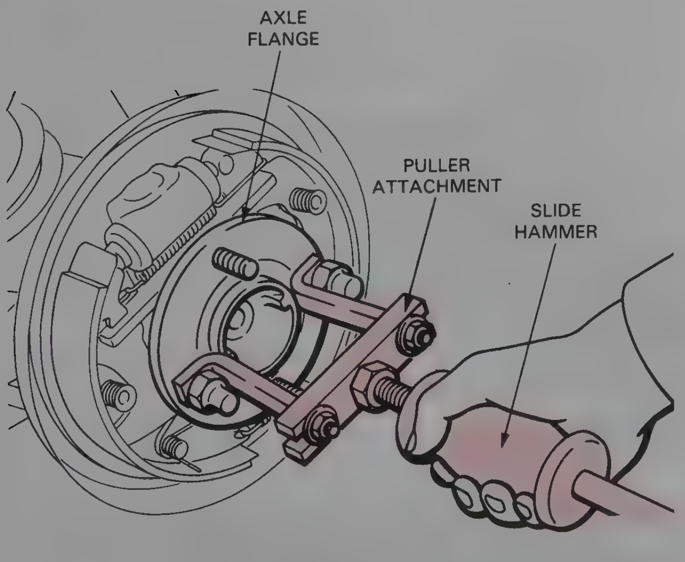


Fig. 30-12. Using a slide hammer and puller attachment to remove rear axle. (Chrysler)

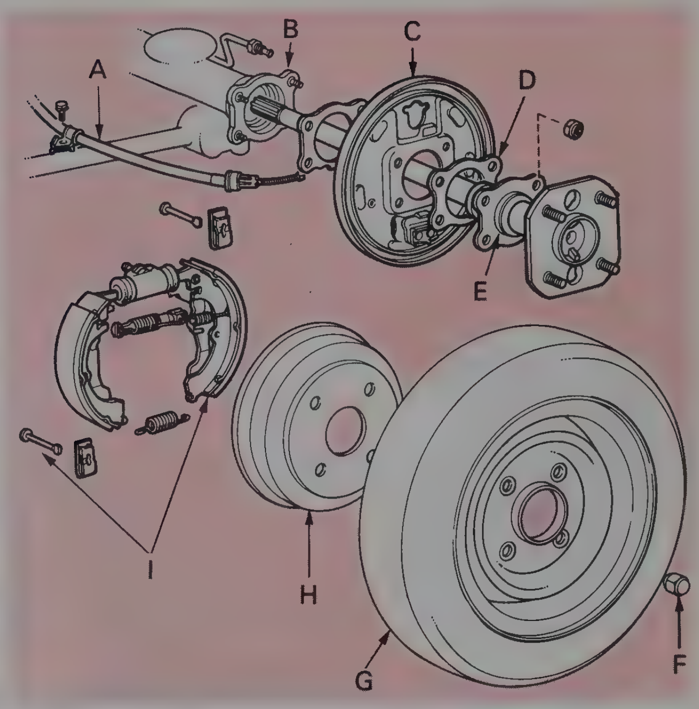


Fig. 30-13. Typical rear axle assembly. A—Parking brake cable. B—Axle housing end. C—Backing plate. D—Axle shaft. E—Axle bearing. F—Wheel nut. G—Wheel and tire. H—Brake drum. I—Brake shoe assembly. (Toyota)

FLANGED AXLE REMOVAL — INNER LOCK TYPE

On some rear axle applications, the axle is retained with an inner end lock (C-washer type). To remove such an axle, pull wheel and brake drum. Drain differential housing and remove inspection plate. Remove differential pinion shaft (NOT DRIVE PINION SHAFT). Push the axle inward as far as it will go. This will free the C-lock from the recess in the axle side gear. Remove C-lock. Withdraw axle. See Fig. 30-14.

AXLE REMOVAL — TAPERED END TYPE

In some cases, the wheel hub or hub-drum assembly is attached to the axle by means of a taper and key, Fig. 30-15, or taper, key and splines, Fig. 30-16. This requires the use of a heavy-duty puller to remove the hub. Fig. 30-15 illustrates how the hub is attached to the tapered axle end.

After pulling the wheel, remove hub retaining nut. Attach a wheel hub puller. Make certain parking brake is released. Hold the puller body and tighten screw. Make certain screw will not damage axle threads. Use thread protectors if needed. Tighten screw. If hub will not break loose, rap end of puller screw sharply. Tighten and rap again. Repeat until hub breaks free. Use a long handled wrench to apply adequate pressure to the puller screw. This will help avoid the necessity of hammering which can cause bearing damage if excessive.

A. DRIVE COUPLING
B. THRUST WASHER
C. LOCK NUT
D. OIL SEAL
E. DRIVE PINION
F. PINION FRONT BEARING
G. PRELOAD SPACER
H. PINION REAR BEARING
I. PINION DEPTH SHIM
J. THRUST WASHER
K. PINION GEAR
L. SHIM/SPACER
M. DIFFERENTIAL BEARING
N. AXLE SHAFT C-LOCK
O. LOCK SCREW
P. PINION SHAFT
Q. DIFFERENTIAL COVER
R. RING GEAR BOLT
S. SIDE GEAR
T. BEARING CAP
U. BEARING CAP BOLT
V. DIFFERENTIAL COVER GASKET
W. AXLE SHAFT
X. DIFFERENTIAL CASE
Y. RING GEAR
Z. DIFFERENTIAL CARRIER

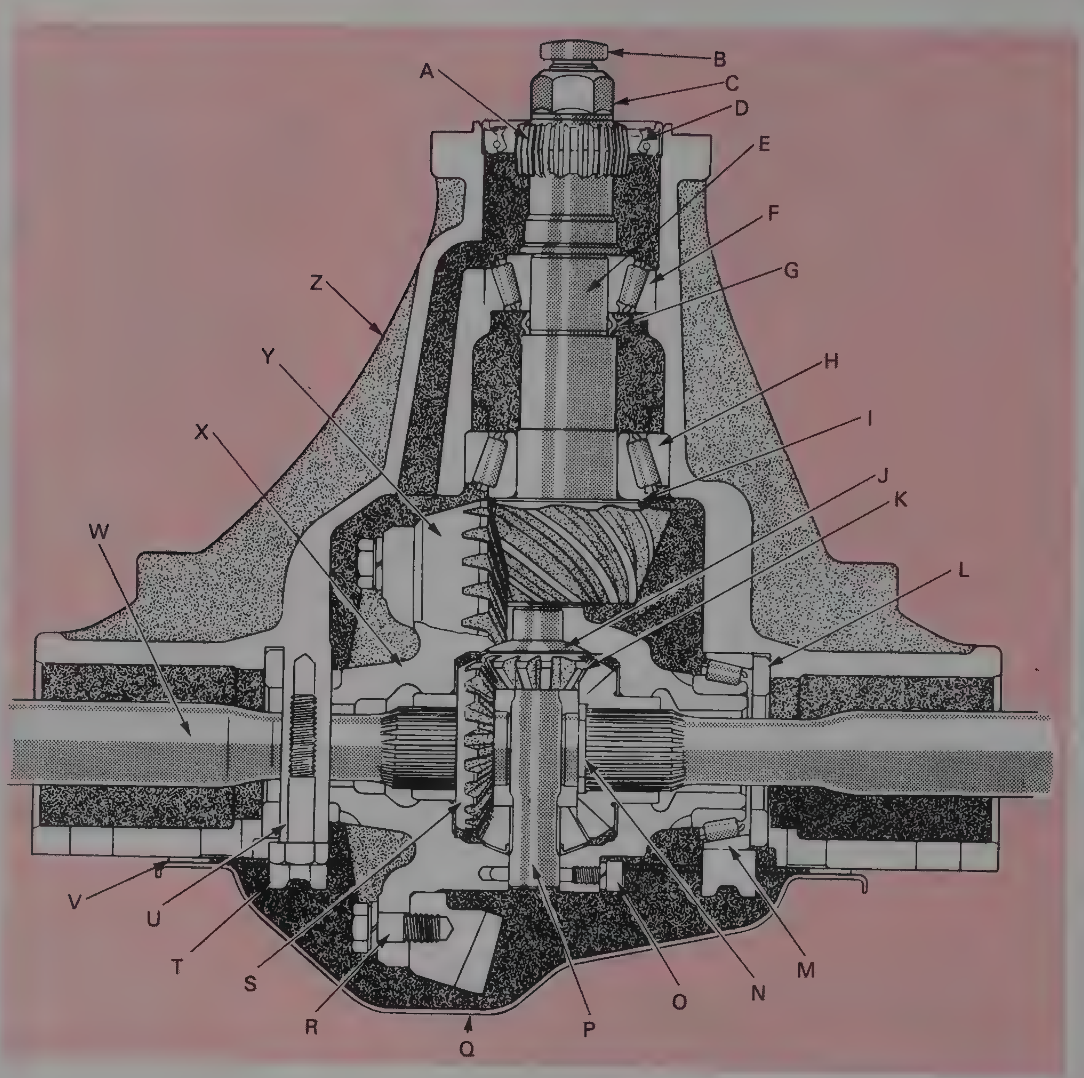


Fig. 30-14. These axles are retained by C-locks (N) on axle shaft inner ends. Note how differential pinion shaft (P) keeps axle ends in outward position, thus forcing C-locks into recesses in side gears, (S). Also note special drive coupling (A) used with extension housing (torque tube) setup. (Chevrolet)

The use of a puller nut knockout (heavy nut screwed on axle end and then pounded to remove hub), instead of a regular puller, is NOT recommended.

Fig. 30-17 shows a wheel hub being removed with a special hub puller.

Remove brake line fitting from the wheel cylinder. Remove parking brake cable connection if desired. Remove backing plate nuts and pull backing plate assembly from the housing end.

Watch carefully for shims between plate and housing when removing backing plate. Tie them together and place where they will not be damaged.

Attach a puller to the axle. Pull axle. See Fig. 30-18.

BROKEN AXLE REMOVAL

When an axle has broken in service, a short piece or stub may be left in the housing. This section can often be retrieved by using a powerful magnet on a long handle, a tapered spring spiral on a handle (spring is turned and climbs up on broken section) or by some other special tool.

Examine the break carefully by placing the broken ends together. If the break is clean (no missing pieces), drain and flush the housing thoroughly.

If small pieces are missing from the break, clean and flush until all particles are removed. In some cases, complete disassembly of the differential and drive pinion assembly is required.

Remember that a very tiny particle of axle shaft can ruin bearings and gears.

AXLE INSPECTION

When an axle is removed, it should be carefully washed and blown dry. DO NOT WASH SEALED BEARINGS.

Inspect the splines for evidence of wear. Look care-

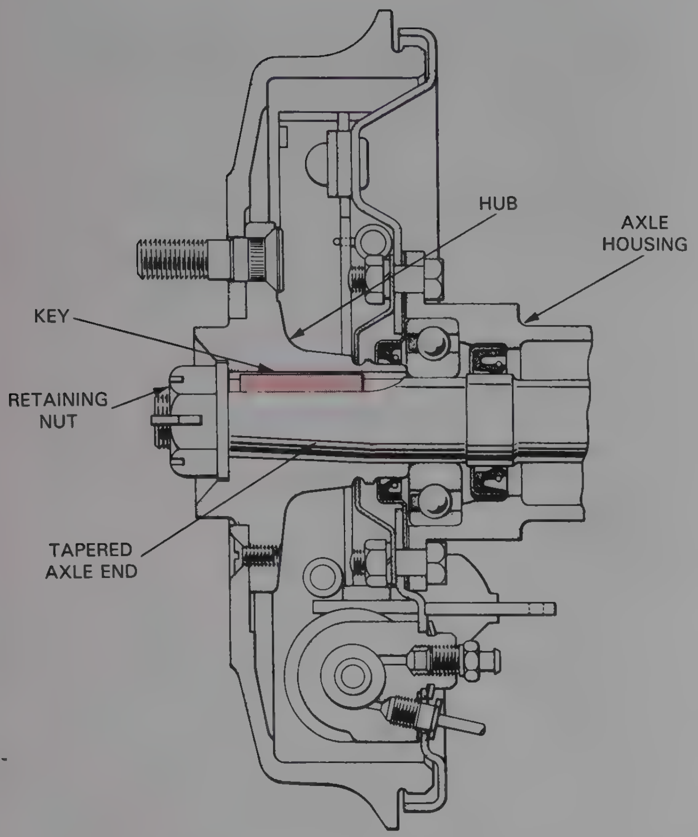


Fig. 30-15. Hub attached to axle by using a tapered end axle and key. Retaining nut holds hub firmly against taper and key. (British-Leyland)

fully for indications of twisting. See Fig. 30-19.

Check the oil seal contact surfaces. Polish off any burrs.

Shaft may be placed on V-blocks or between centers to check for runout, bending, or other problems. Fig. 30-20 illustrates the use of V-blocks and a dial indicator to check axle for runout. Fig. 30-21 shows the axles being held between centers while checking for bends and flange runout with indicator.

Inspect wheel lugs (on flange type axles) and replace any that are broken or stripped. Use a press, Fig. 30-22.

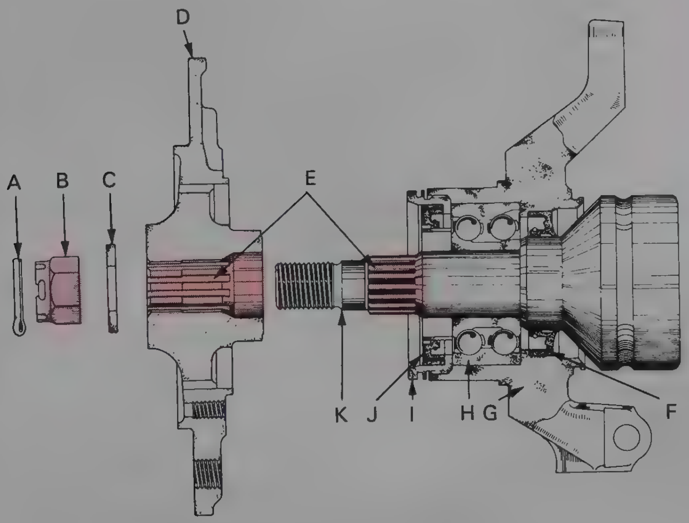


Fig. 30-16. Hub secured to axle with splines and retaining nut. A—Cotter pin. B—Castle retaining nut. C—Washer. D—Hub. E—Splines. F—Seal. G—Steering knuckle housing. H—Double-row ball bearing. I—Nut. J—Seal. K.—Axle (drive). (Saab)

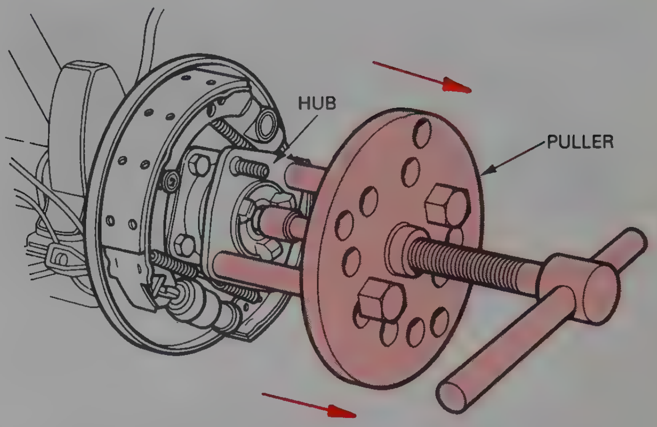


Fig. 30-17. Using a heavy-duty puller to remove wheel hub from tapered axle. (British-Leyland)

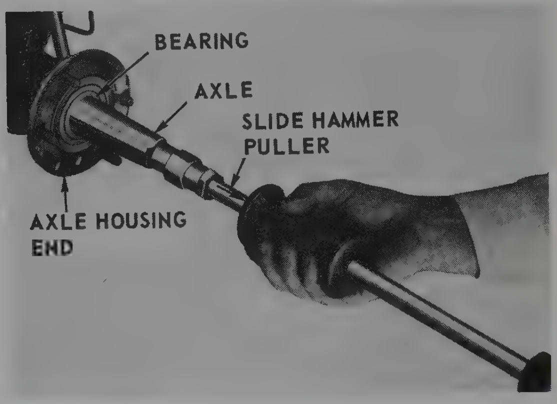


Fig. 30-18. Pulling a tapered end axle. Note that backing plate has been removed from axle housing. (Jeep)

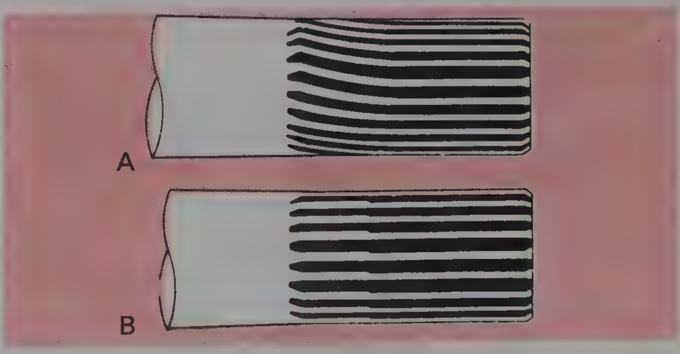


Fig. 30-19. Axle damage. A—Axle has been twisted. B—Splines have step wear (worn thin where axle engages gears). (Isuzu)

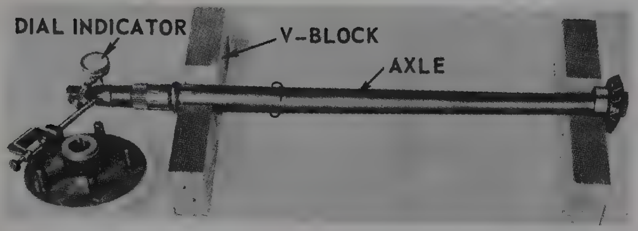

DIAL INDICATOR
V-BLOCK
AXLE

Fig. 30-20. Using V-blocks and dial indicator to check axle for runout. (American Motors)

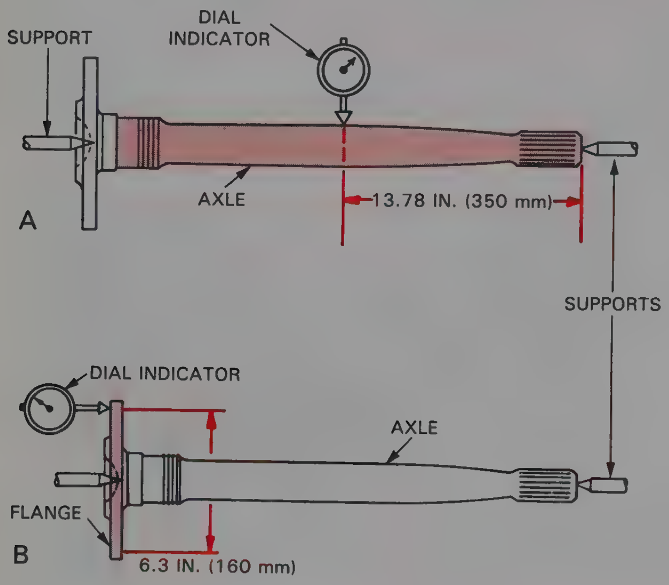

SUPPORT
DIAL INDICATOR
AXLE
A
13.78 IN. (350 mm)
SUPPORTS
DIAL INDICATOR
AXLE
FLANGE
B
6.3 IN. (160 mm)

Fig. 30-21. A—Checking axle for bend with a dial indicator. B—Indicator placed against flange to measure flange runout. Note that axles are supported on tapered centers. (Chevrolet)

Discard shafts showing any signs of twisting, excessive wear, or runout beyond specifications.

AXLE OIL SEAL REPLACEMENT

Following axle removal, always install new oil seals.

Some installations utilize two oil seals — one on the inside of the bearing and another on the outside. The bearing is either sealed for life, or depends upon periodic applications of wheel bearing grease. When the wheel bearing is lubricated by the differential lubricant, only an outer seal is used.

A slide hammer puller with a hook nose is very handy for removing the housing inner seal. When pulling the seal, avoid scoring the housing seal counterbore, Fig. 30-23.

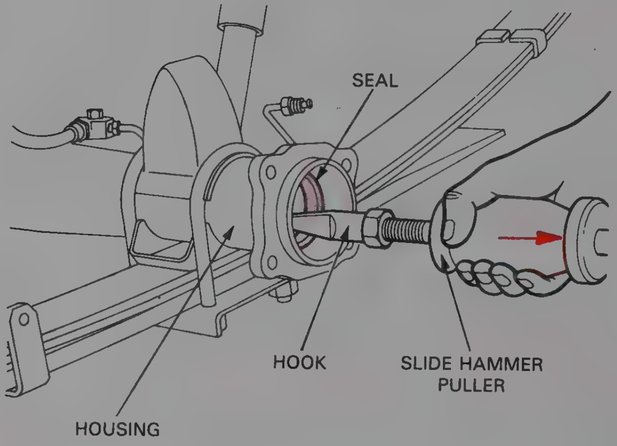

SEAL
HOOK
SLIDE HAMMER PULLER
HOUSING

Fig. 30-23. Pulling axle housing oil seal. (Chrysler)

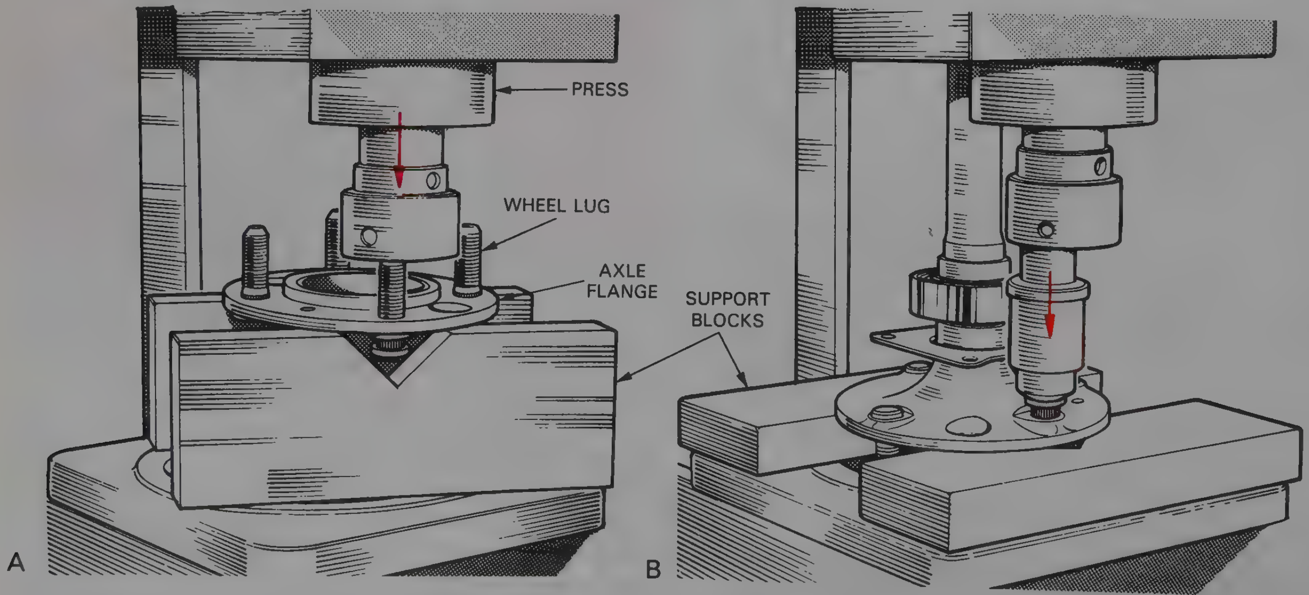

PRESS
WHEEL LUG
AXLE FLANGE
SUPPORT BLOCKS
A
B

Fig. 30-22. Replacing a damaged wheel lug. A—Press is forcing lug from flange. B—New lug is being pressed into position. (Plymouth)

Clean seal counterbore. Remove nicks and burrs. If seal is made of leather, soak in light oil for 30 minutes. Coat outer seal edge with nonhardening sealer. Apply gear oil to seal lip. Using a suitable tool, drive seal into place. Seal lip must face inward. Drive squarely and to proper depth. See Fig. 30-24.

The outer seal may be built into the bearing itself. It may also be incorporated in the oil seal retainer.

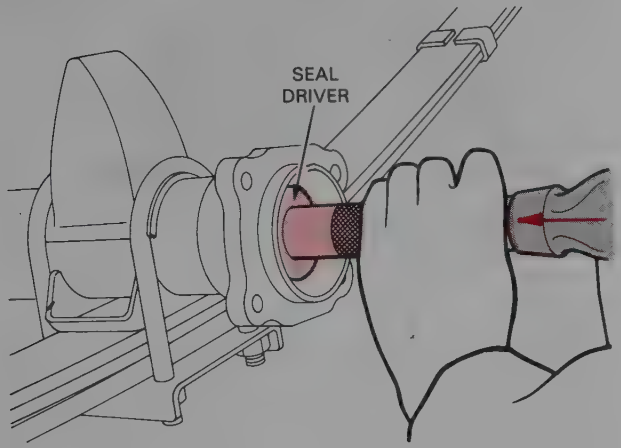


Fig. 30-24. Driving an axle seal into position with a seal driver. (Chrysler)

REAR WHEEL BEARING REPLACEMENT

Where a bearing retainer ring is used, place the axle so that the ring rests on a solid support such as a vise. Slide a protective sleeve up to the ring. Notch the ring with a grinder and break it away with a hammer and chisel. See Fig. 30-25. DO NOT GRIND COMPLETELY THROUGH THE RING AS THIS WOULD DAMAGE THE AXLE. MAKE CERTAIN A PROTECTIVE SLEEVE IS USED.

Slide the retainer ring from the shaft. Set the axle up in a press (a puller can also be used) so that the bearing may be grasped while the axle is forced through the bearing. Grasp the bearing, not the retainer plate. Make certain the axle flange is clear of puller and press.

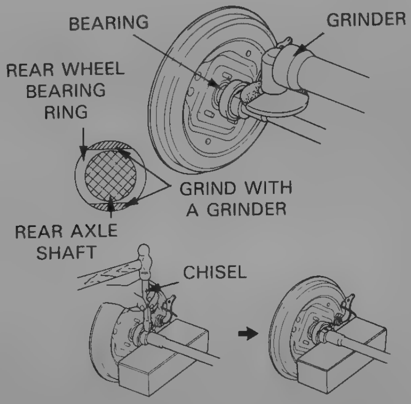


Fig. 30-25. Notch bearing ring with grinder. Then, crack ring with hammer and chisel.

USE A BEARING COVER, SUCH AS IN FIG. 30-26. ALSO USE PROTECTIVE GOGGLES TO PREVENT INJURY FROM FLYING PARTS IN THE EVENT THE BEARING EXPLODES UNDER PULLING PRESSURE. See A, Fig. 30-26.

Clean the axle and coat bearing face and retaining ring contact surface with a film of lubricant. Use the type used for ball joints.

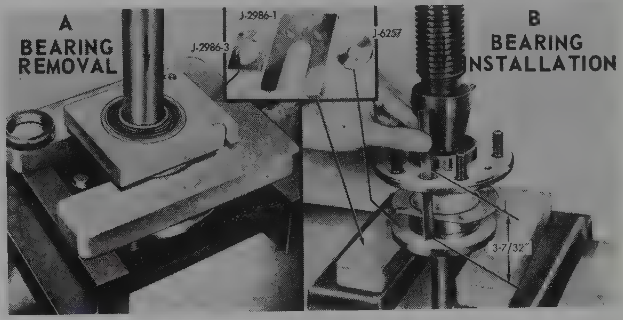


Fig. 30-26. A—Wheel bearing removal. B—Installation. (Cadillac)

Put the retaining flange into position on the axle. Slide the new bearing on the axle. BEARING MUST FACE IN THE DIRECTION SPECIFIED. Set axle up in press so that the bearing INNER RACE is supported. DO NOT INSTALL BY EXERTING PRESSURE ON THE OUTER RACE.

Before pressing bearing into place, check retainer plate for proper positioning and bearing for correct installation. Press bearing on the shaft as specified. Note how bearing is pressed on a specific distance from the flange surface in B, Fig. 30-26.

Slide the retaining ring into position. It must face as recommended. Set axle in press so that retaining ring

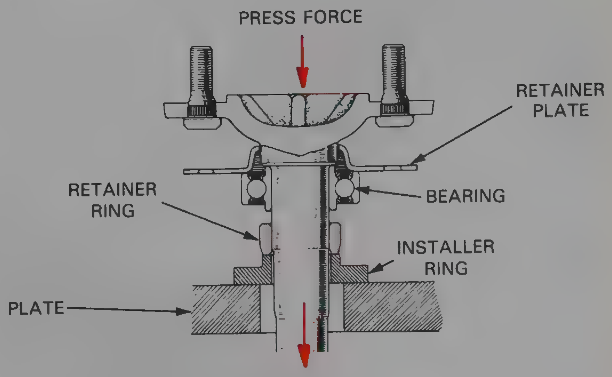


Fig. 30-27. Pressing a bearing retaining ring into position. Note how installer ring supports retainer ring. (Toyota)

is well supported. SUPPORT RING AROUND ITS FULL CIRCUMFERENCE – NOT IN JUST TWO SPOTS. Force axle through the ring until the ring just contacts the bearing. See Fig. 30-27. NEVER TRY TO PRESS THE BEARING AND RETAINING RING ON AT THE SAME TIME. ALWAYS USE A NEW RETAINING RING.

An assembled bearing and retaining ring is illustrated in Fig. 30-28.

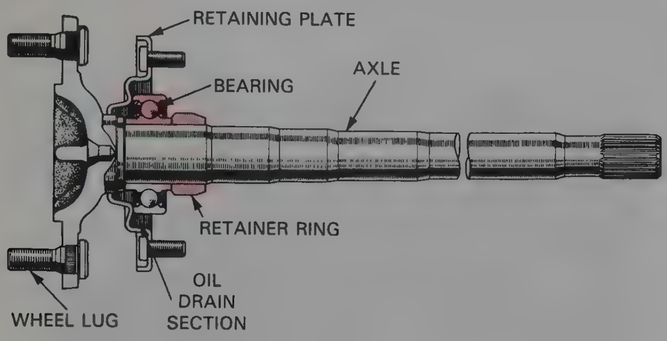


Fig. 30-28. Bearing and retainer ring installed on axle. (Toyota)

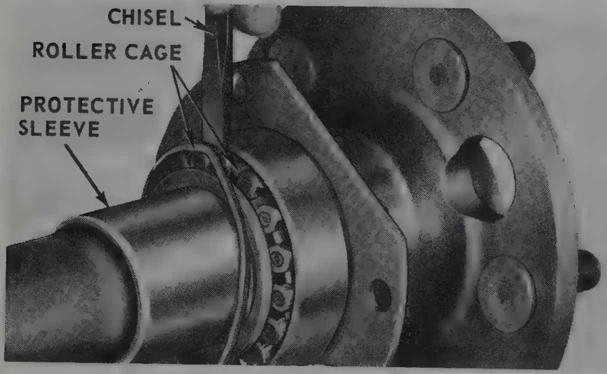


Fig. 30-29. Cutting off roller cage outer section. Note protective sleeve. (Plymouth)

One axle setup has the retainer plate so close to the bearing that the bearing cannot readily be grasped for pulling. When this is the case, cut off the roller cage outer section, Fig. 30-29. Grind off a section of the inner race. Use a sleeve to protect axle. Then remove the rollers one by one, Fig. 30-30.

Cut out the remaining portion of the cage and pull the outer race from the axle. The inner race may now be grasped for pulling. Some bearings are retained with a locknut. Remove bearing carefully on these to avoid possible thread damage.

AXLE INSTALLATION

Axle must be CLEAN. If the wheel bearings were damaged, clean and flush the housing. Place a new gasket on the housing end. Place a new O-ring gasket on the bearing outer face.

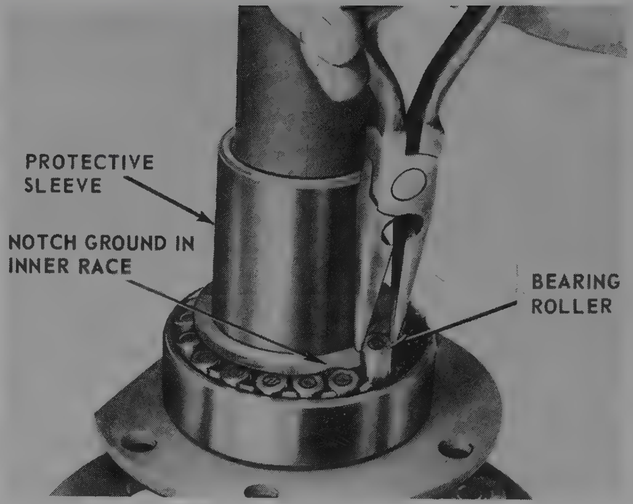


Fig. 30-30. Removing bearing rollers. Note notch ground in inner race.

Coat the length of the axle with clean gear oil. Lubricate bearing counterbore in the housing. Lubricate bearing if required. Slide the axle into the housing. PASS THE SPLINED END AND AXLE LENGTH THROUGH THE OIL SEAL VERY CAREFULLY TO AVOID DAMAGE.

As the shaft is passed into the housing, support the weight. Engage splined end in axle side gear. Align bearing and start into housing counterbore. Sometimes the axle is longer on one side than the other. Make sure axle is installed on the correct side.

ALIGN RETAINER PLATE SO THAT THE OIL DRAIN SECTION, FIG. 30-28, IS OVER THE DRAIN HOLE IN THE BACKING PLATE. GASKET MUST BE ALIGNED TO EXPOSE OIL DRAIN HOLE. DO NOT PLUG HOLE WITH SEALER. If the oil drain is not aligned, oil leakage past the bearing will pass into the brake assembly. Oil can then reach the shoes and drum or pads and rotor, ruining the linings.

When installing an axle with a tapered roller bearing and shims, make certain shims are clean and in the proper position. Use gaskets and sealer where required.

On axles with the hub attached to a tapered end, install the shims, backing plate, and an outer seal. Use new gaskets and coat with sealer. Tighten fasteners. Attach brake lines and bleed brakes (see chapter on brake service).

AXLE END PLAY

After the axle retainer plate fasteners are torqued, check the axle for proper end play. Attach a dial indicator firmly to the axle flange and adjust the indicator stem against the backing plate.

Pull the axle in and out and note total reading. This will be the axle end play.

Some axles are designed so that end play is controlled by the play in the wheel bearings (ball type) or by shims (tapered roller), or by an adjusting nut (tapered roller bearings) on one end of the axle housing. Follow manufacturer's specifications. See Fig. 30-31.

When attaching wheel hubs to a tapered axle end, make certain the key is in position. Lubricate hub and taper. Draw the hub retaining nut (lubricate nut and washer) up to the specified torque. Rap the hub soundly with a lead hammer and recheck torque. Use a new cotter pin to secure nut. If cotter pin hole in axle is not aligned with nut castellations, increase torque until cotter pin will enter. NEVER BACK NUT OFF TO ALIGN PIN. Some manufacturers specify that the hub be a certain distance from the end of the axle. Follow specifications. See Fig. 30-32.

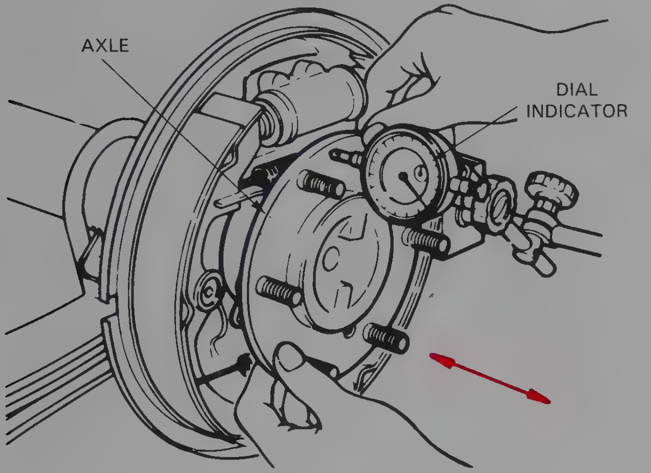

AXLE
DIAL INDICATOR

Fig. 30-31. Checking axle end play. Move axle back and forth while watching indicator. (Nissan)

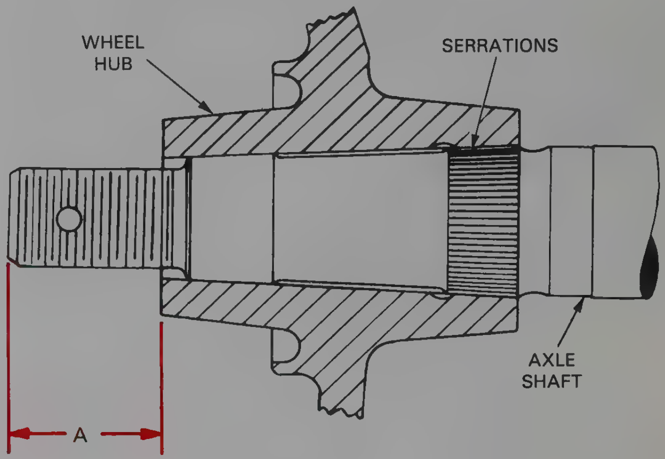

WHEEL HUB
SERRATIONS
AXLE SHAFT
A

Fig. 30-32. Measure distance from end of axle shaft to face of wheel hub, A. Note serrations which firmly engage hub when properly seated. A key (not shown) is also used. (AMC)

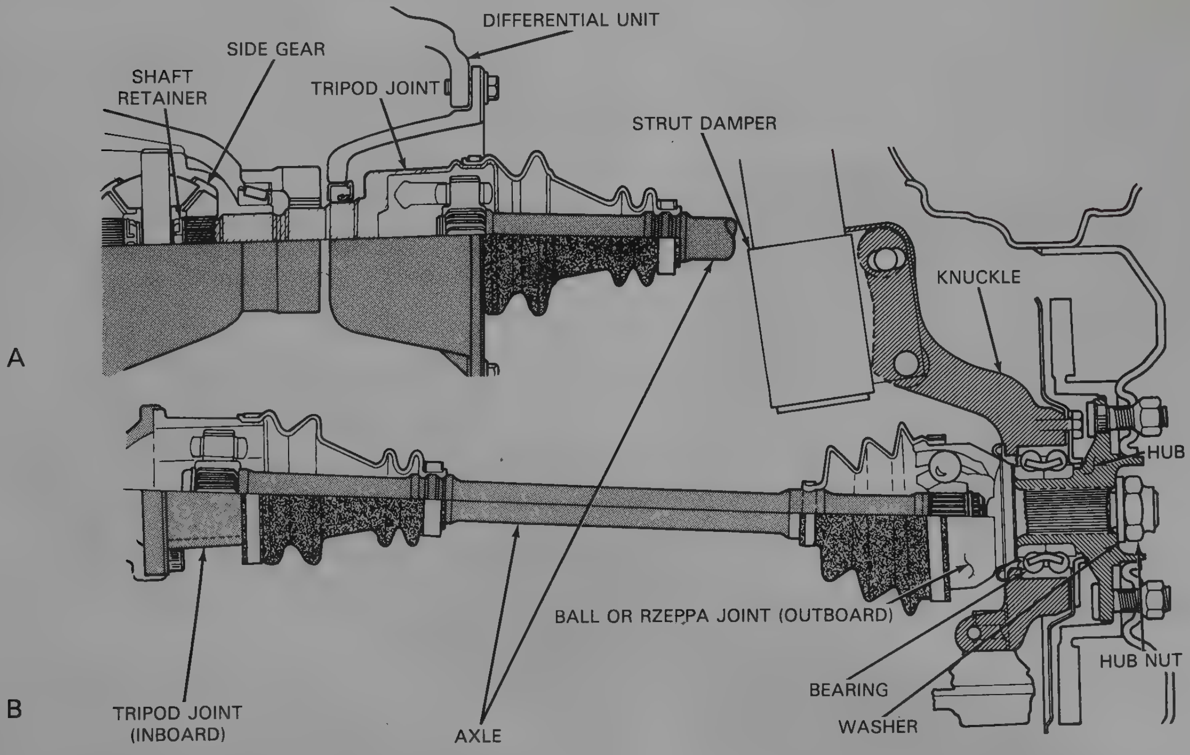

DIFFERENTIAL UNIT
SIDE GEAR
SHAFT RETAINER
TRIPOD JOINT
STRUT DAMPER
KNUCKLE
A
HUB
BALL OR RZEPPA JOINT (OUTBOARD)
HUB NUT
BEARING
WASHER
B
TRIPOD JOINT (INBOARD)
AXLE

Fig. 30-33. One front-wheel drive axle and universal joint setup. Joints used on this unit are of constant velocity tripod and ball type. Note somewhat different inboard joint attachment methods: A—Automatic transmission. B—Manual transmission. (Chrysler)

AXLE REMOVAL — FRONT-WHEEL DRIVE

Vehicles that are equipped with a front-wheel drive setup generally have independent suspension. These require a somewhat different axle (axle drive shaft) removal procedure than does the conventional solid axle housing just discussed.

The one or two-piece front-wheel drive axles are usually retained by inboard (inside) and outboard (outside nearest wheel) universal joints. Fig. 30-33 depicts one such arrangement.

The following is a general procedure. Follow manufacturer's recommendations for your vehicle.

Remove the battery negative cable. Remember some vehicles use dual batteries. Vehicle should be elevated with a jack and placed on jack stands or with a floor lift. This will provide the necessary work space. Remove the wheels where necessary. Mark each axle so they can be returned to their original locations during reassembly. Failure to do this could lead to severe vibrations and early part failure.

Next, remove the protective dust boots (where used) and universal joint fasteners. Some cars require the partial or complete removal of the steering knuckle assembly to allow for axle removal. Fig. 30-34 shows the axle being removed.

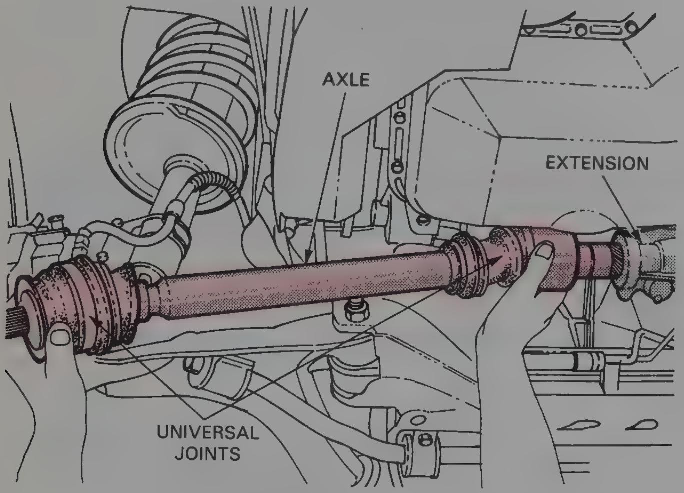


Fig. 30-34. Front axle being removed from vehicle. Note that universal joints have not been disassembled for axle removal. (Chrysler)

AXLE UNIVERSAL JOINT — DISASSEMBLY

There are two basic universal joint types; TRIPOD and the BALL (also called Rzeppa) type. These are constant velocity designs. Fig. 30-35 pictures both the tripod and ball units.

Disassembly of either type begins with the removal of the protective boot that covers the joint. Next, remove any snap rings and carefully separate the joint. Be sure to keep parts in proper order if required by the manufacturer. Clean all parts, except rubber boot, thoroughly in solvent. Inspect for possible damage. Replace or repair parts as required. Fig. 30-36 illustrates a tripod type joint being disassembled after boot removal.

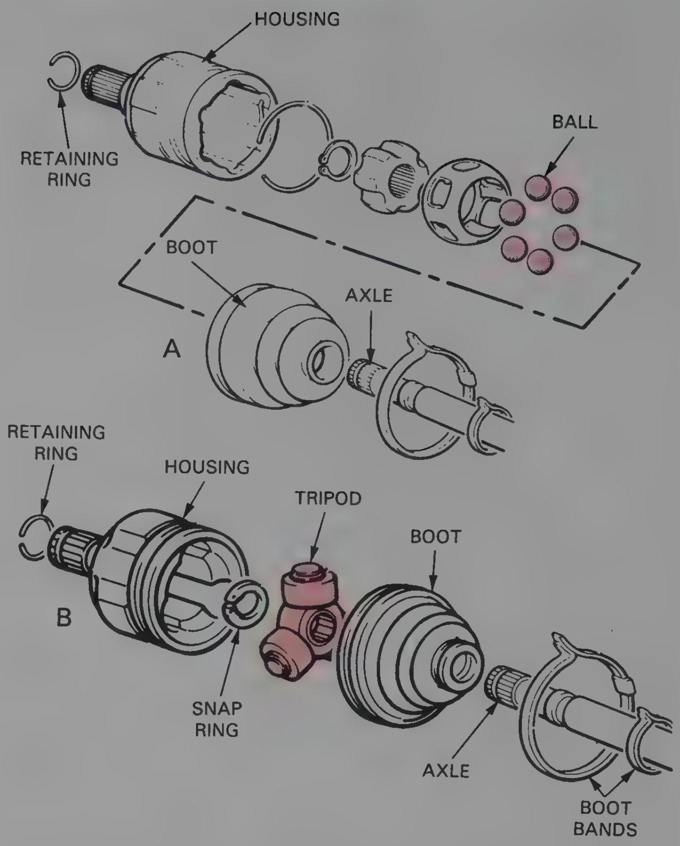


Fig. 30-35. A—Exploded view of a Ball (Rzeppa) joint. B—Tripod joint. Note that tripod setup is similar to a ball and trunnion universal joint. (Chrysler)

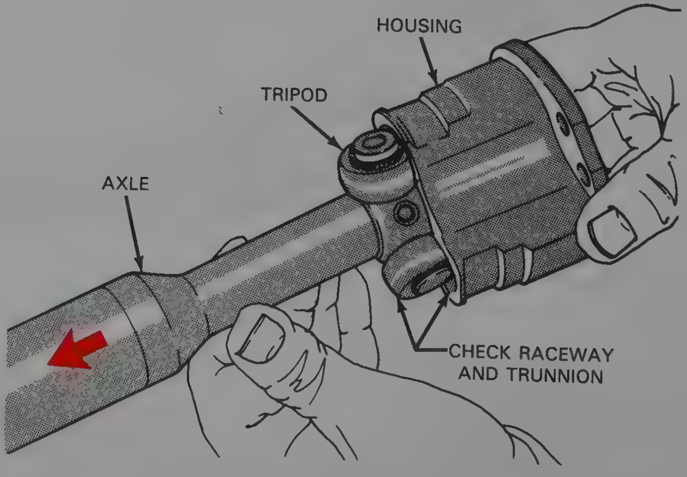


Fig. 30-36. After boot removal, axle and tripod are pulled from housing. (Plymouth)

AXLE UNIVERSAL JOINT — ASSEMBLY

Joints are usually assembled in the reverse order of disassembly. Be sure to replace all defective parts. Lubricate where required. Align any witness marks. If a new joint is used, discard housing end cover (if equipped). Follow manufacturer's recommendations for reassembly.

AXLE INSTALLATION

Reverse the removal procedure. Align witness marks. Lubricate where necessary. Be sure to follow the manufacturer's instructions exactly.

CAUTION! Be sure to torque ALL fasteners and double-check all areas. A failure in this area can lead to loss of vehicle control and passenger injury.

DIFFERENTIAL REMOVAL

Drain the housing. Remove both axle shafts. Disconnect propeller shaft. Check drive pinion shaft preload.

If the differential carrier is of the removable type, unscrew the fasteners and remove the carrier. WATCH OUT — IT IS HEAVY.

Place the carrier in a repair stand such as shown in Fig. 30-37.

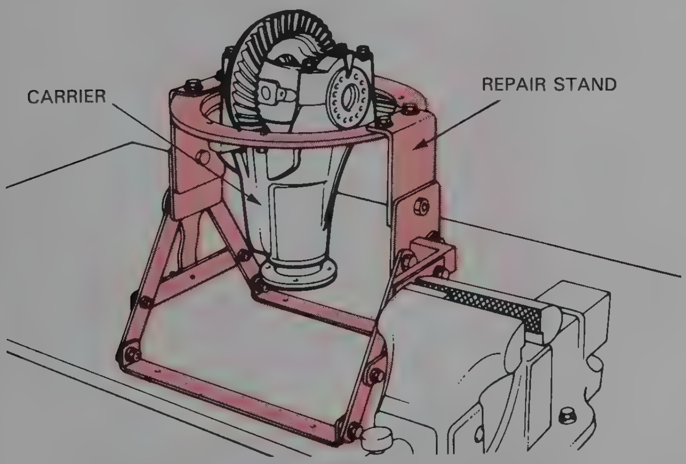


Fig. 30-37. Differential carrier bolted to a repair stand.

If the carrier is of the integral type, it may be necessary to remove the entire housing. Check manufacturer's manual. Fig. 30-38 shows a repair stand designed to handle the entire housing.

MARK PARTS BEFORE REMOVAL

Before removing the differential case side bearing caps, make certain each cap and adjusting nut (where used) is marked. The caps and carrier are factory marked in Fig. 30-39.

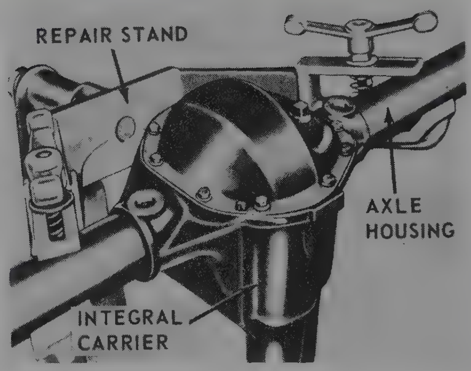


Fig. 30-38. This repair stand will hold entire axle housing. (Ford)

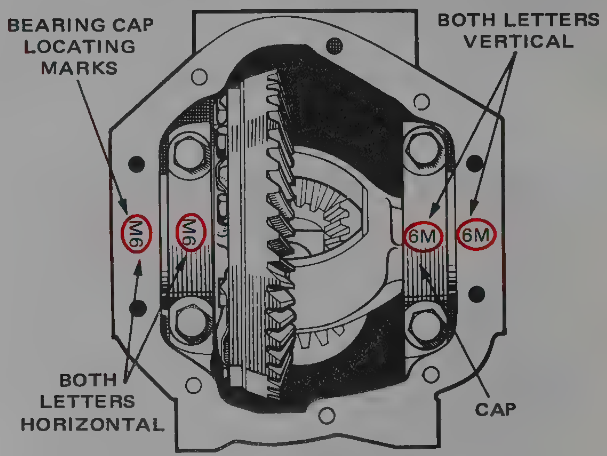


Fig. 30-39. These differential case side bearing caps are factory marked for proper positioning. (British-Leyland)

If no marks are visible, mark with a scribe and prick punch, as shown in Fig. 30-40.

It is also good practice to check the backlash between ring and pinion gears before differential case removal (see section on adjusting backlash later in this chapter). Tooth contact pattern and bearing preload can also be checked.

Remove the case bearing cap fasteners and caps. Rap caps to remove. Do not mar cap parting surface. If they are the mechanically adjustable type shown in Fig. 30-40, the differential case will lift out readily.

If the shim is of the adjusted preload type shown in Fig. 30-39, use a couple of pinch bars or a differential puller to force case out of housing. Tie each shim pack together and identify. DO NOT INTERCHANGE SHIMS OR SHIFT FROM ONE SIDE TO THE OTHER, Figs. 30-41 and 30-42.

DO NOT DROP THE SIDE BEARING OUTER RACES. IDENTIFY TO PREVENT MIXING.

A special adapter is sometimes attached by means of two ring gear cap screws. A slide hammer puller is

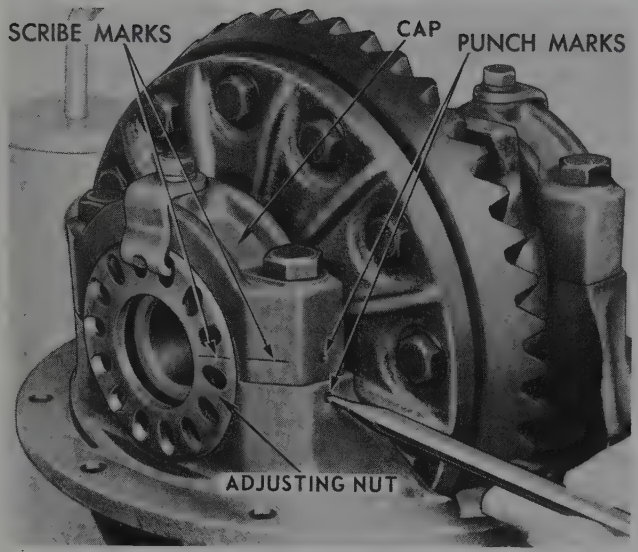

SCRIBE MARKS
CAP
PUNCH MARKS
ADJUSTING NUT

Fig. 30-40. Marking differential side bearing caps and bearing adjusters before removal. (Plymouth)

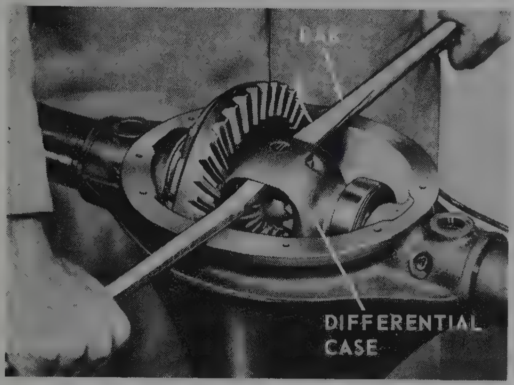

BAR
DIFFERENTIAL CASE

Fig. 30-41. Using pinch bars to force differential case out of carrier.

then connected to the adapter. The case is withdrawn with a series of sharp blows.

Another technique involves using a differential housing spreader, Fig. 30-43. The spreader is installed as directed and the turnbuckle expanded. Never expand the housing more than specified, Fig. 30-44. Consider a .020 in. (0.51 mm) expansion the absolute limit. Following expansion, remove case and immediately release spreader.

DIFFERENTIAL DISASSEMBLY, INSPECTION, AND REPAIR

Use a suitable puller to remove the differential case side bearings (if required), Fig. 30-45. Tie to outer races or cups.

Free ring gear by removing fasteners. Tap gear free of case. Drive out pinion gear lock pin and remove pinion shaft, Fig. 30-46, or remove pinion shaft lock screw, Fig. 30-47.

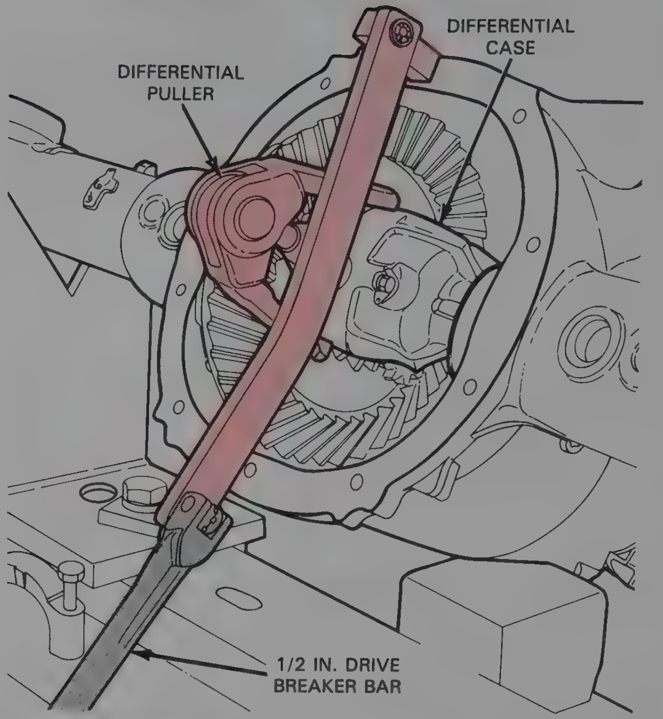

DIFFERENTIAL CASE
DIFFERENTIAL PULLER
1/2 IN. DRIVE BREAKER BAR

Fig. 30-42. Removing a differential case with a special puller. (Cadillac)

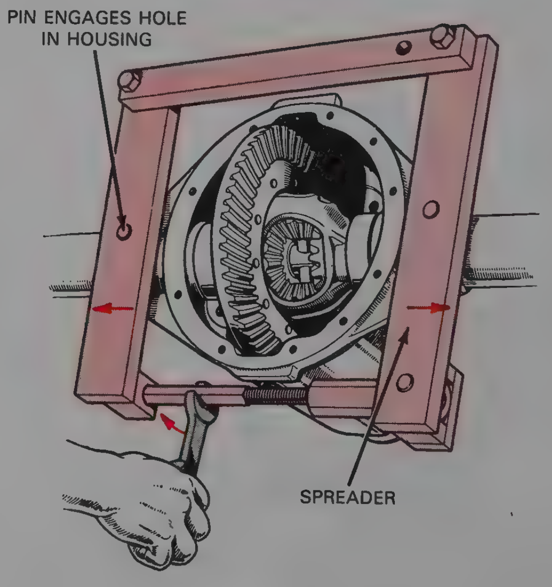

PIN ENGAGES HOLE IN HOUSING
SPREADER

Fig. 30-43. Using a housing spreader. Never expand housing more than .020 in. (0.51 mm).

Remove the pinion gears. Wash all parts and blow dry. Inspect pinion and axle side gears for excessive wear or chipping, Fig. 30-48.

Check ring and drive pinion gear for scoring, chipping, and other damage. Fig. 30-49 shows a heavily damaged ring and pinion. Note scoring on ring gear and mutilated teeth on the drive pinion gear.

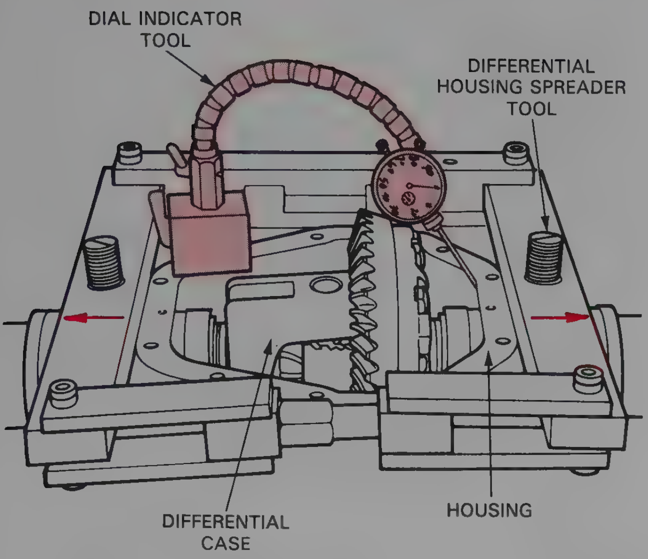

DIAL INDICATOR TOOL
DIFFERENTIAL HOUSING SPREADER TOOL
DIFFERENTIAL CASE
HOUSING

Fig. 30-44. Using a dial indicator to measure housing spread. DO NOT exceed manufacturer's recommendations. (Ford)

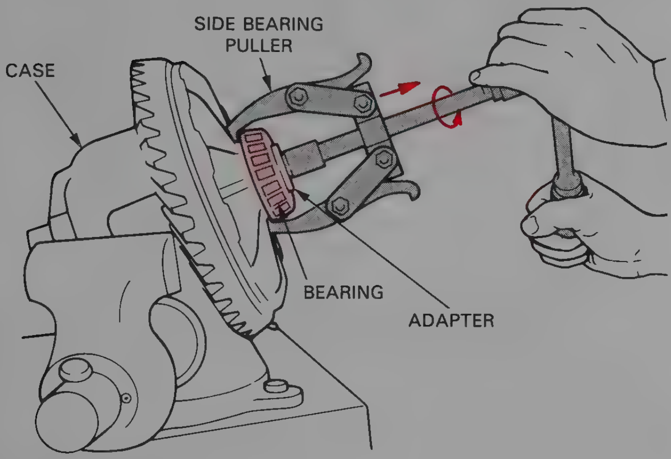

SIDE BEARING PULLER
CASE
BEARING
ADAPTER

Fig. 30-45. Pulling a differential case side bearing. Be careful not to damage bearing mounting surface on case with puller. (Cadillac)

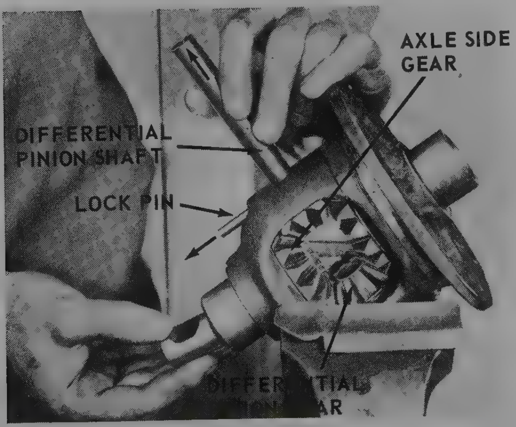

AXLE SIDE GEAR
DIFFERENTIAL PINION SHAFT
LOCK PIN
DIFFERENTIAL PINION GEAR

Fig. 30-46. Removing differential pinion shaft.

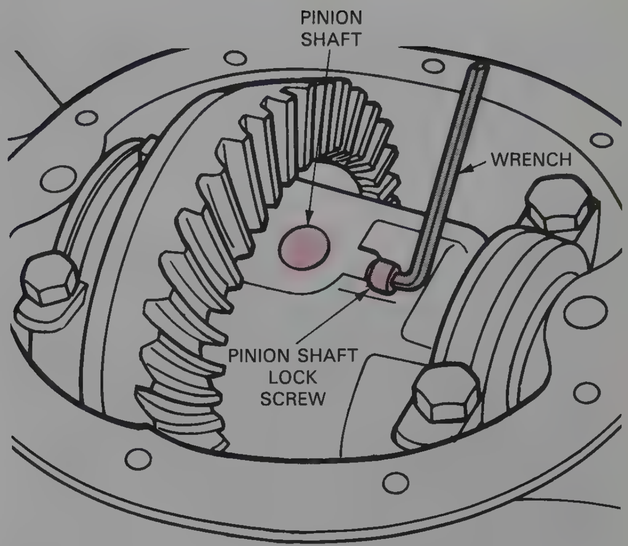

PINION SHAFT
WRENCH
PINION SHAFT LOCK SCREW

Fig. 30-47. Removing pinion shaft lock screw to free pinion shaft for removal. (Chevrolet)

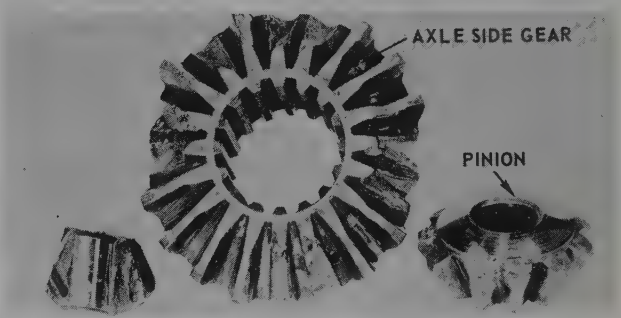

AXLE SIDE GEAR
PINION

Fig. 30-48. These pinion gears and axle side gears are badly damaged. (Eaton)

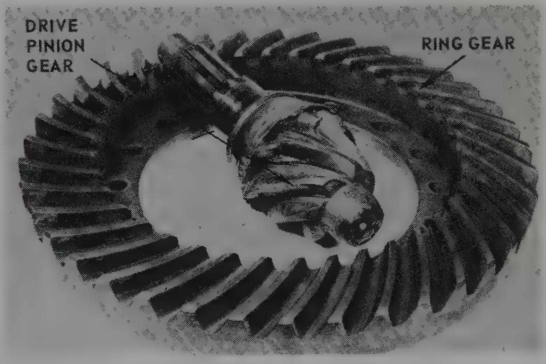

DRIVE PINION GEAR
RING GEAR

Fig. 30-49. Heavy ring gear and drive pinion damage. (Eaton)

CHECK DIFFERENTIAL CASE FOR WEAR AND RUNOUT

Examine the case side bearing contact surfaces. They must be perfect with no sign of the bearing inner race having turned on them. Thrust washer surfaces inside of case must be smooth and free of excessive wear.

Place the case in a set of V-blocks and check the ring gear flange attaching surface with a dial indicator. Runout must be within specifications, Fig. 30-50.

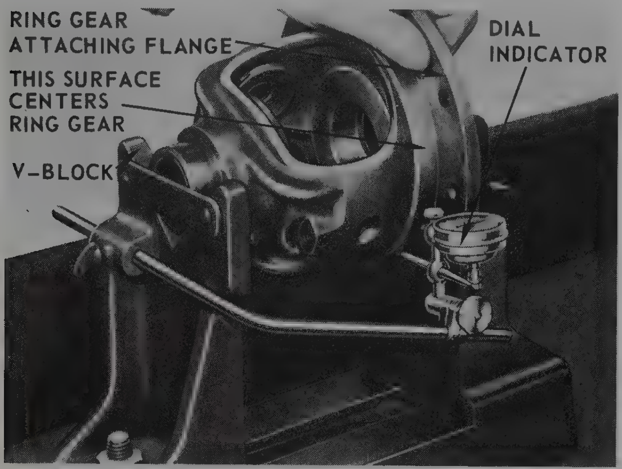


Fig. 30-50. Checking ring gear centering surface for runout. Attaching flange must also be checked. (G.M.C.)

If new side bearings are required, lubricate case contact surface. Install shims if used between case and bearing. Drive or press bearings into position. APPLY FORCE TO INNER CONE – NOT TO ROLLERS, Fig. 30-51.

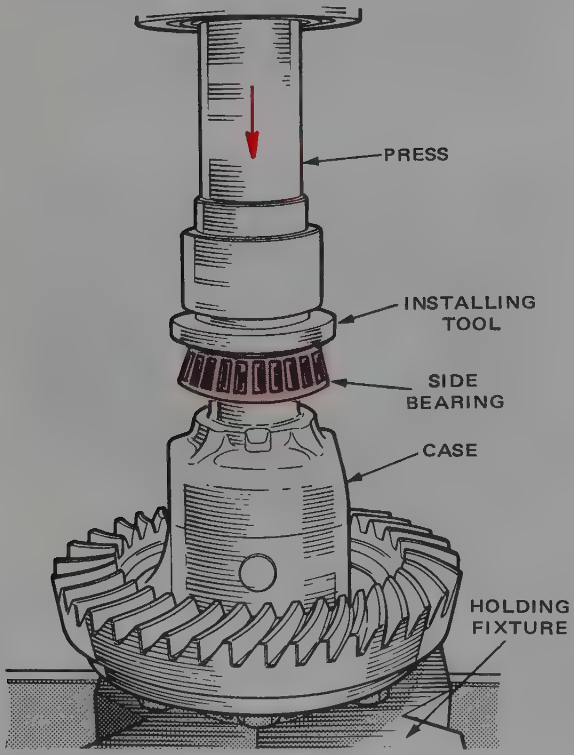


Fig. 30-51. Installing a new differential side bearing. Installing tool must apply force to INNER RACE ONLY! (Plymouth)

When new side bearings are used, use new outer cones also. Lubricate the case, thrust washers, pinions, and axle side gears. Place side gears and washers into position in the case. "Walk" the pinion gears around the axle side gears until aligned with the shaft hole. Insert pinion shaft spacer block and lock pin.

Rotate the gears a few times. Then check clearance between side gear and thrust washer, Fig. 30-52. NOTE: Where inner axle end C-locks are used, it will be necessary to remove the pinion shaft and spacer block to install the axles.

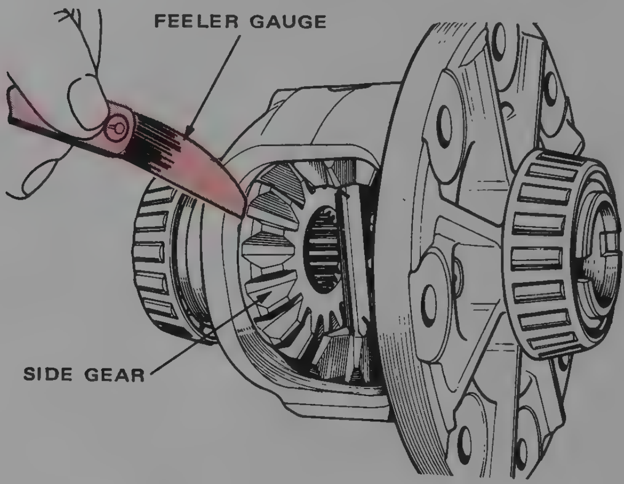


Fig. 30-52. Method of checking clearance between axle side gear and thrust washer. (Plymouth)

NEW RING GEAR INSTALLATION

WHEN EITHER A NEW RING GEAR OR PINION DRIVE GEAR IS REQUIRED, THEY MUST BE REPLACED AS A SET. NEVER CHANGE ONE WITHOUT THE OTHER. ALWAYS CHECK THE NEW RING AND PINION TO MAKE CERTAIN THAT THEY ARE A MATCHED SET. MATCH NUMBER ON THE PINION MUST BE THE SAME AS THAT APPEARING ON THE RING. Note the numbers on the ring and pinion in Fig. 30-53. The number 4 appears on both ring and pinion, thus indicating they are a matched set. The + 1/2 is a marking to indicate the variation from a standard pinion depth setting. This number is needed to determine the thickness of the pinion shaft shim pack. This will be discussed under pinion drive gear installation.

Check the case flange and attaching surface of the ring gear for the slightest sign of burring, dirt, and other problems. The two contact surfaces must be spotlessly clean.

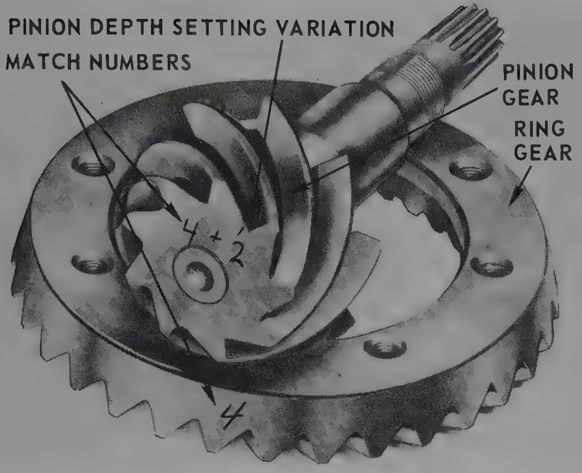


Fig. 30-53. Typical ring and pinion gear markings to indicate a matched set.

Insert several guide studs in the ring gear to provide accurate alignment with the differential case. Position the ring gear. Lubricate all attaching cap screws. Start cap screws into ring gear and run up alternately until ring gear just touches case. Remove guide studs and run up remaining fasteners.

Tighten ring gear fasteners alternately, first on one side, then on the other. Bring to one-half recommended torque the first time around. Go over the fasteners a second time bringing to full torque. If guide studs are not available, run a cap screw into the ring, one on each side. Pull up to align ring with case.

IMPORTANT: USE RING GEAR FASTENERS ONLY. DO NOT SUBSTITUTE WITH REGULAR CAP SCREWS. FASTENERS MUST BE LUBRICATED. FASTENERS MUST BE A SNUG FIT IN BOTH CASE AND RING GEAR. DO NOT USE LOCK WASHERS UNLESS USED IN THE ORIGINAL INSTALLATION. SOME CAP SCREWS REQUIRE THE USE OF A LIQUID ADHESIVE. FOLLOW MAKER'S RECOMMENDATIONS.

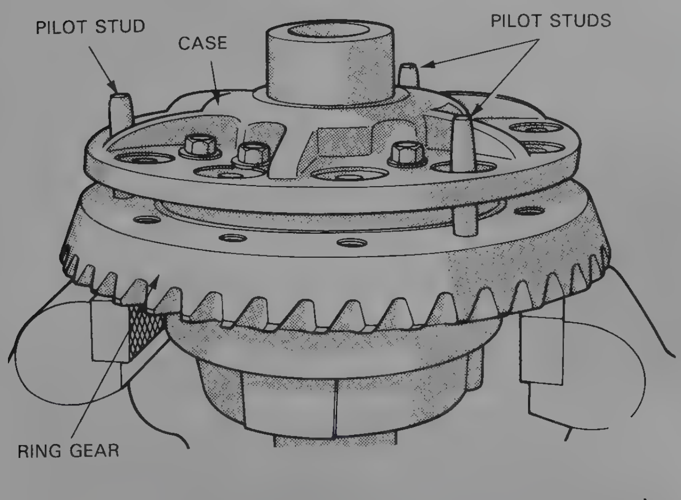


Fig. 30-54. During assembly, pilot studs provide accurate ring gear-to-case alignment. (Plymouth)

Fig. 30-54 illustrates the use of pilot studs to align ring gear.

Some ring gear setups require the gear to be brought to a specified temperature BEFORE installation. Use a special heating oven or oil bath heater. NEVER attempt to heat the ring gear with an acetylene torch! This can remove the tempering.

GEAR RATIO MUST BE CORRECT

The new ring and pinion set must have the correct number of teeth so that the desired gear ratio (number of times pinion gear turns to drive ring once) is maintained. If the ratio is to be changed, make certain that the new set is adaptable to the differential case. On some installations, different cases are used, depending upon gear ratio.

CHECK RING GEAR RUNOUT

After the differential is mounted in the carrier, check the runout of the ring gear. If beyond specified limits, remove ring gear. Check for nicks, burrs, and dirt on the contact surfaces. Reassemble and check runout again. RUNOUT MUST BE WITHIN SPECIFIED LIMITS, Fig. 30-55.

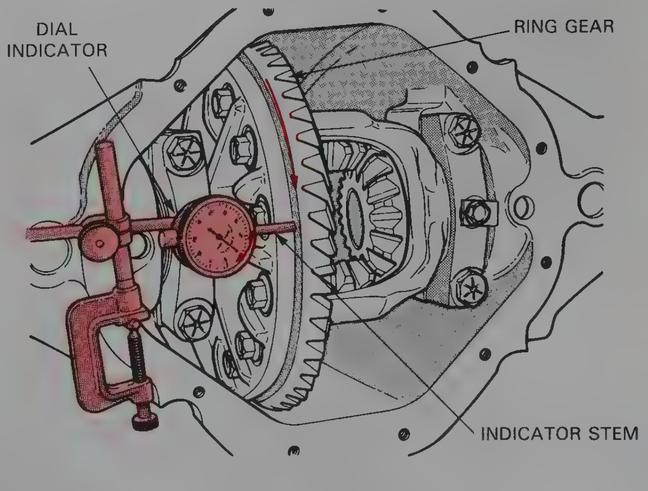


Fig. 30-55. Checking new ring gear runout with a dial indicator. (British-Leyland)

PINION DRIVE GEAR REMOVAL

Remove the pinion flange retaining nut. Remove pinion flange (see replacing pinion shaft seal and/or pinion flange in first part of chapter).

With differential case removed, tap pinion shaft inward until free.

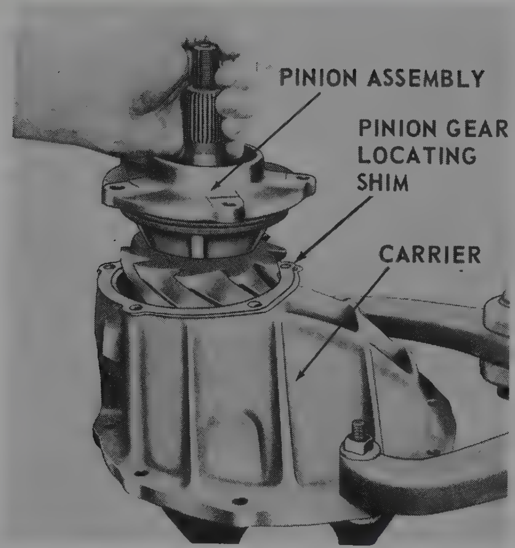

PINION ASSEMBLY
PINION GEAR LOCATING SHIM
CARRIER

Fig. 30-56. Ford type pinion assembly pulls from base of carrier. Note shim pack.

On one Ford type pinion arrangement, the pinion assembly pulls off the carrier after removing the fasteners, Fig. 30-56.

An exploded view of this pinion assembly is pictured in Fig. 30-57. Notice the small roller pilot bearing. It fits into a bore in the carrier and supports the front of the pinion gear.

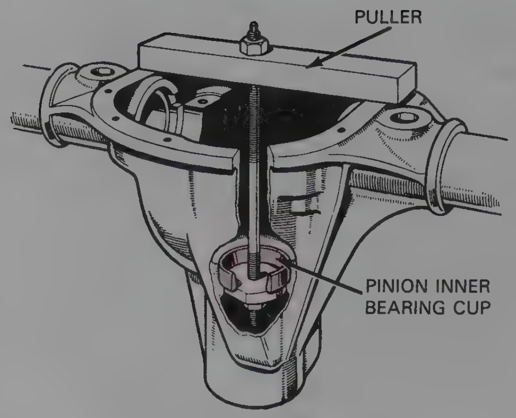

PULLER
PINION INNER BEARING CUP

Fig. 30-58. Pulling pinion inner bearing cup from carrier.

Drive in squarely to the correct depth. If adjusting shims are used beneath the inner cup, be certain they are spotlessly clean and in place. If a new pinion gear is being installed, adjust shim pack as required. Fig. 30-59 illustrates a pinion assembly that uses shims to adjust pinion preload and pinion position.

The pinion assembly in Fig. 30-60 uses shims for positioning the pinion gear. Preload is controlled by a collapsible spacer.

Remove the pinion shaft inner bearing, Fig. 30-61.

Lubricate pinion shaft. Install spacer or shim, if used. Drive bearing firmly into position. Place pinion

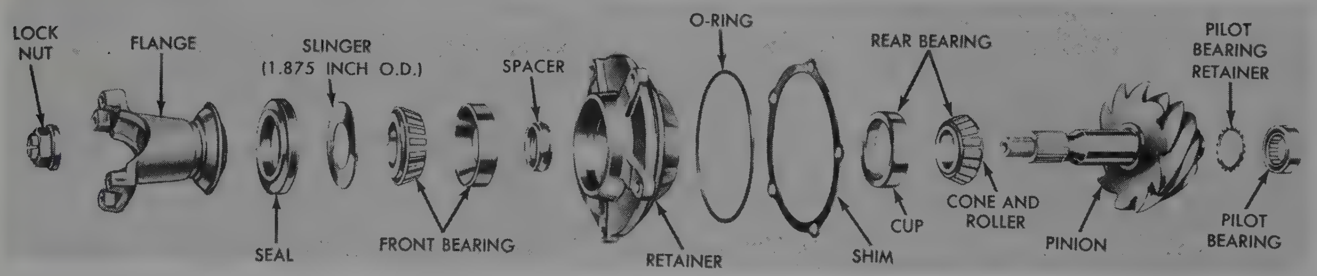

LOCK NUT
FLANGE
SLINGER (1.875 INCH O.D.)
SPACER
O-RING
REAR BEARING
PILOT BEARING RETAINER
SEAL
FRONT BEARING
RETAINER
SHIM
CUP
CONE AND ROLLER
PINION
PILOT BEARING

Fig. 30-57. Exploded view of the Ford type pinion assembly. (Ford)

gear against a soft, clean surface. Apply pressure to inner cone — not to the rollers, Fig. 30-62. If pinion depth must be checked, do not install on pinion shaft until depth check is made.

Be careful to save all shims. Tie individual shims in the pack together and identify as to location. Measure the thickness of each shim and write it down in case shims are lost.

Wash all parts of the assembly and blow dry. Inspect for wear, chipping, and scoring.

INSTALLING NEW PINION BEARINGS

Remove both front and rear bearing cups from carrier. Do not mar the surface of the counterbore during removal. Fig. 30-58 shows the use of a puller in removing a bearing cup.

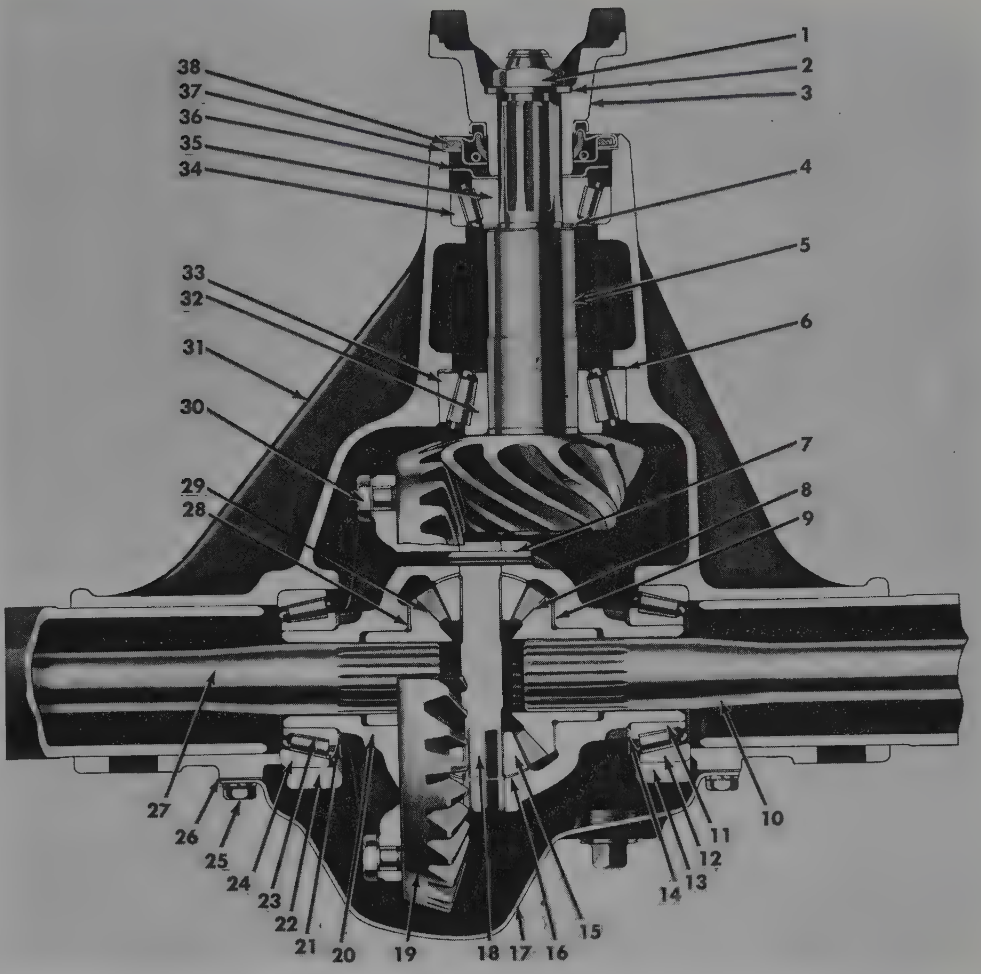
Check the bores. Lubricate and install new cups.

CHECKING AND ADJUSTING PINION DEPTH

Pinion gear depth (distance from face of pinion gear to centerline of ring gear) is CRITICAL.

Each matched ring and pinion set is tested at the factory for the relationship between ring gear and pinion that will produce the best tooth contact pattern. This relationship (pinion depth) is compared to a nominal (standard) pinion depth. The difference is marked on

1. YOKE NUT
2. WASHER
3. PROP. SHAFT YOKE
4. ADJUSTING SHIMS
5. DRIVE PINION
6. ADJUSTING SHIMS
7. LOCK PIN
8. DIFF. SIDE GEAR – R.H.
9. SIDE GEAR THRUST WASHER
10. AXLE SHAFT – R.H.
11. BEARING CONE – R.H.
12. BEARING CUP – R.H.
13. BEARING CAP – R.H.
14. ADJUSTING SHIMS – R.H.
15. DIFFERENTIAL PINION
16. PINION THRUST WASHER
17. HOUSING COVER
18. DIFF. PINION SHAFT
19. DRIVE GEAR
20. DIFFERENTIAL CASE
21. ADJUSTING SHIMS – L.H.
22. BEARING CAP – L.H.
23. BEARING CONE – L.H.
24. BEARING CUP – L.H.
25. CAP SCREW
26. GASKET
27. AXLE SHAFT – L.H.
28. SIDE GEAR THRUST WASHER
29. DIFF. SIDE GEAR – L.H.
30. CAP SCREW
31. DIFFERENTIAL CARRIER
32. BEARING CONE – INNER
33. BEARING CUP – INNER
34. BEARING CUP – OUTER
35. BEARING CONE – OUTER
36. OIL SLINGER
37. OIL SEAL GASKET
38. OIL SEAL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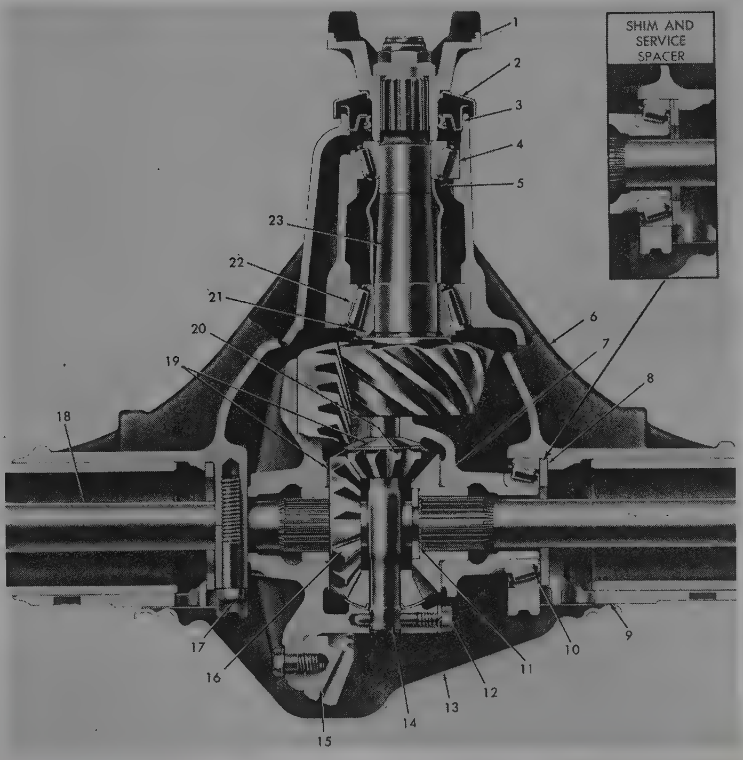
11

Fig. 30-59. This pinion gear assembly uses shims to adjust pinion preload as well as pinion depth.

1. COMPANION FLANGE
2. DEFLECTOR
3. PINION OIL SEAL
4. PINION FRONT BEARING
5. PINION BEARING SPACER (COLLAPSIBLE)
6. DIFFERENTIAL CARRIER
7. DIFFERENTIAL CASE
8. CASE SHIM(S) AND SPACER
9. GASKET
10. CASE OR CARRIER BEARING
11. AXLE C-CLIP
12. PINION SHAFT BOLT
13. DIFFERENTIAL COVER
14. PINION SHAFT
15. RING GEAR
16. DIFFERENTIAL SIDE GEAR
17. CAP BOLT
18. AXLE
19. THRUST WASHERS
20. DIFFERENTIAL PINION GEAR
21. PINION SHIM(S)
22. PINION REAR BEARING
23. DRIVE PINION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SHIM AND SERVICE SPACER
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Fig. 30-60. Pinion gear used with this unit has shims (21) to control pinion depth. A collapsible spacer (5) is used to preload bearings.

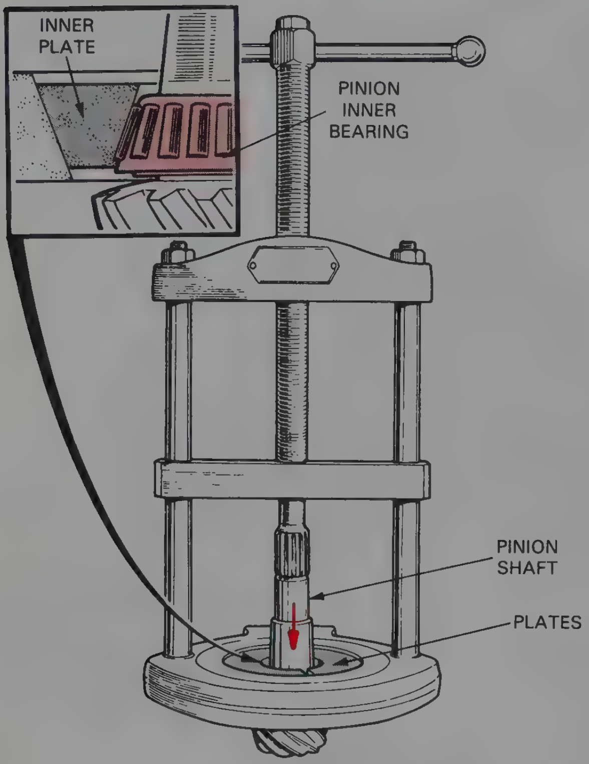

INNER PLATE
PINION INNER BEARING
PINION SHAFT
PLATES

Fig. 30-61. Removing a pinion shaft inner bearing with a special puller setup. Note that inner plate (closest to bearing) is notched which allows it to firmly grasp bearing. (Plymouth)

the pinion gear.

If the pinion had to be closer to the ring gear centerline, the amount in thousandths marked on the pinion is preceded by a – (minus) sign. If the pinion depth was such that the pinion was a greater distance from the centerline, the amount will be preceded by a + (plus) sign. Note the + marked on the pinion gear in Fig. 30-63. This indicates that this particular pinion will have to be adjusted so that it is .001 in. (0.025 mm) further away from the centerline than the nominal distance.

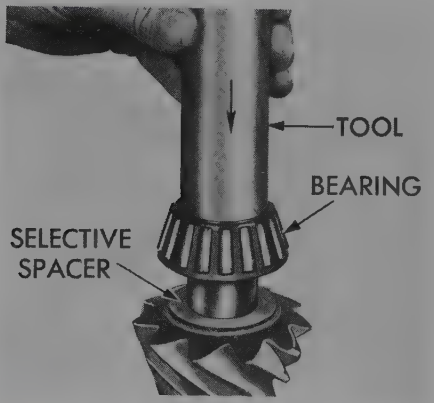

TOOL
BEARING
SELECTIVE SPACER

Fig. 30-62. Driving pinion shaft bearing. Note pinion depth spacer in position. (Dodge)

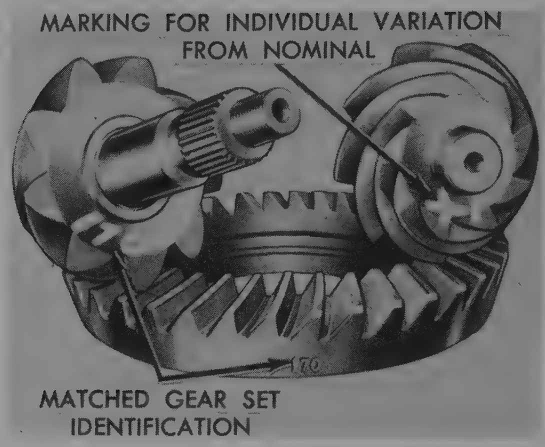

MARKING FOR INDIVIDUAL VARIATION FROM NOMINAL
MATCHED GEAR SET IDENTIFICATION

Fig. 30-63. This pinion gear will have to be set at a depth .001 in. greater than nominal amount. (Ford)

The position of the pinion in relation to the ring gear centerline for a + (plus) and a – (minus) pinion marking is pictured in Fig. 30-64. Note that the minus mark pinion will set closer to the centerline and the plus mark pinion further away.

Pinion depth is controlled by placing shims between the pinion gear and the bearing, Figs. 30-60, 30-62, 30-64; between the inner bearing outer race or cup and the carrier, Fig. 30-59; or between the pinion retainer and carrier face, Fig. 30-56.

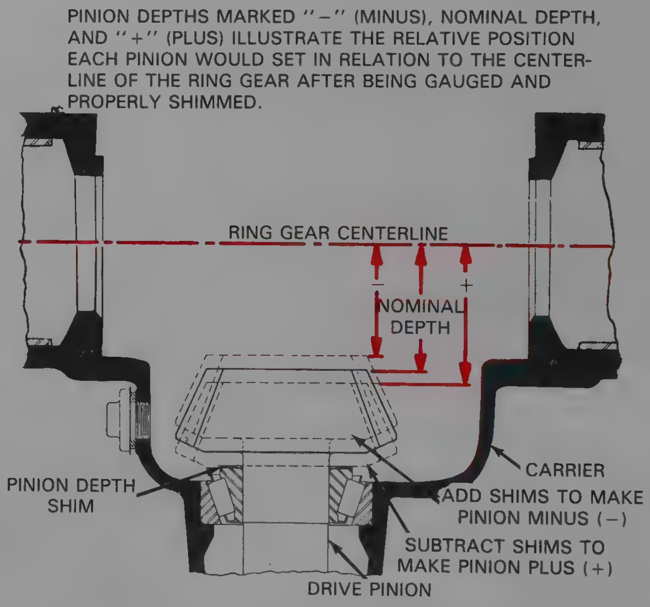

PINION DEPTHS MARKED "–" (MINUS), NOMINAL DEPTH, AND "+" (PLUS) ILLUSTRATE THE RELATIVE POSITION EACH PINION WOULD SET IN RELATION TO THE CENTERLINE OF THE RING GEAR AFTER BEING GAUGED AND PROPERLY SHIMMED.
RING GEAR CENTERLINE
–
+
NOMINAL DEPTH
PINION DEPTH SHIM
CARRIER
ADD SHIMS TO MAKE PINION MINUS (–)
SUBTRACT SHIMS TO MAKE PINION PLUS (+)
DRIVE PINION

Fig. 30-64. Relative distance from ring gear centerline for a pinion marked with a minus (–), a plus (+), and a nominal (0). (Pontiac)

As illustrated in Fig. 30-64, shims must be added for minus marked pinions and removed for plus markings. An exception to this is the Ford type in Fig. 30-56 in which the addition of shims is required for a plus marking.

Pinion depth should be checked with special gauges when a new ring and pinion set, new pinion bearings, or new carrier is installed.

If the original ring and pinion, inner bearing, and carrier will be reused, the original shim pack will give the proper depth.

To set the pinion depth, use a special gauge designed for that purpose. There are numerous types available.

One type of setting gauge is shown in Fig. 30-65. The bearings are lubricated and held in position while the gauge plate and clamp plate are secured with the clamp screw. Note gauge body resting in case side bearing bores.

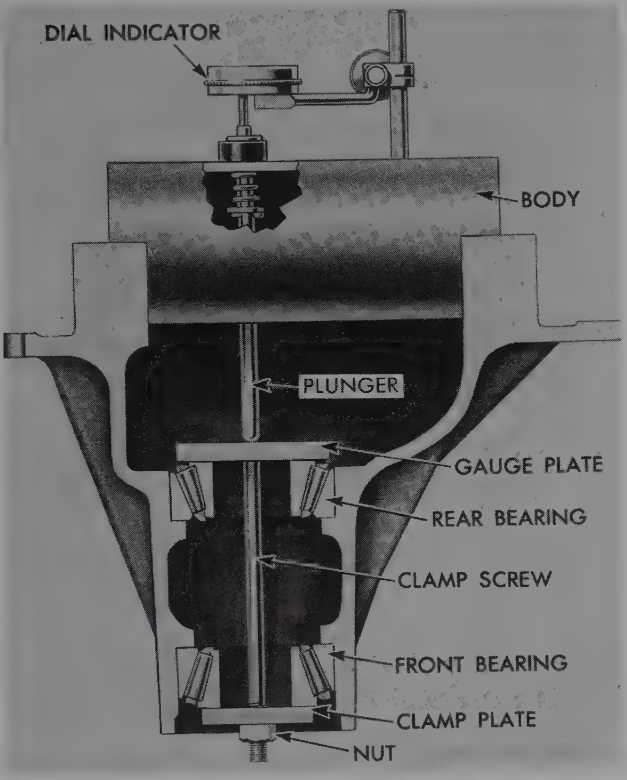


Fig. 30-65. One type of pinion setting gauge.

The clamp screw is tightened until the bearings are preloaded to 20 inch-pounds (2.26 N·m).

Place the gauge body in the case side bearing bores. Bores and gauge must be CLEAN, Fig. 30-66.

Mount a dial indicator on gauge body. Indicator stem must contact body plunger. Swing gauge body so that plunger is CLEAR OF GAUGE PLATE. Set indicator to zero.

Swing the gauge body in the bores so that the plunger moves across the gauge plate. Swing back and forth until highest reading is noted, Fig. 30-66.

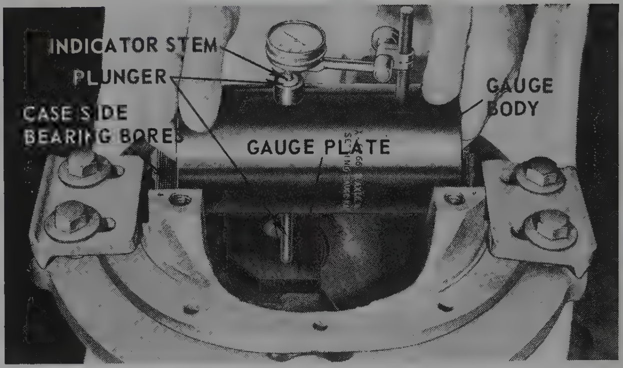


Fig. 30-66. Checking pinion setting gauge reading.

This particular setting gauge is used for pinions with a somewhat different marking system than the plus or minus previously mentioned. Note the number on the pinion in Fig. 30-67.

Write down the pinion setting mark. From this number, subtract the highest gauge reading obtained. For example, the pinion in Fig. 30-67 is marked with the number 46. If the highest gauge reading was 20, subtract 20 from 46, leaving a difference of 26. This means that a shim pack .026 in. (0.66 mm) thick should be used to produce the proper pinion depth setting.

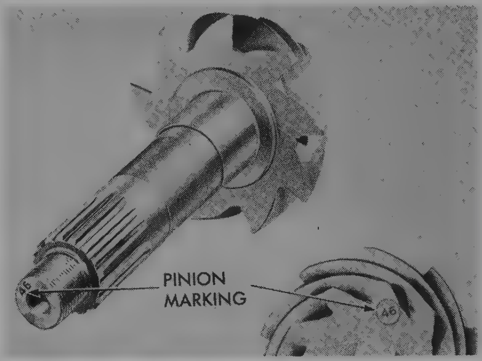


Fig. 30-67. Another type of pinion depth setting mark. (Chevrolet)

Another technique involves the use of a different gauge plate. The reading from the indicator is subtracted from the number 100. The difference represents the thickness of the basic shim pack needed. The plus or minus amount marked on the pinion is subtracted or added to the basic shim pack thickness as required.

Another type of gauging device is being used in Fig. 30-68. A special gauge block is inserted in the pinion bearings and brought to specified torque. The arbor is held in place by hand or with bearing cups. Selective thickness spacers are tried between the face of the gauge block and arbor. When a spacer that will just fit is found, write down the thickness. Examine the pinion for a plus or minus amount. If the chosen spacer is

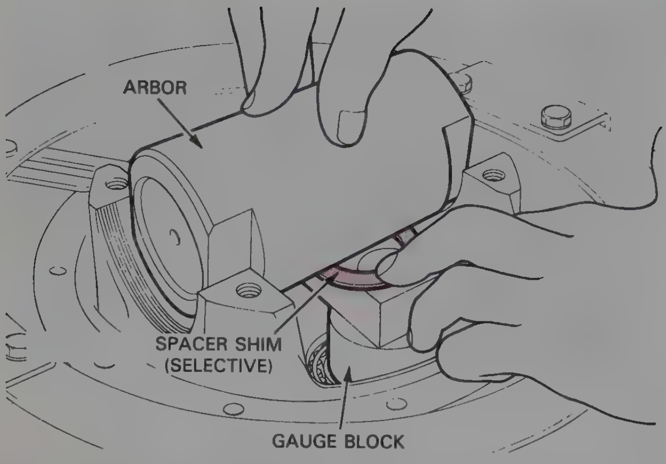


Fig. 30-68. Selecting proper pinion depth adjusting shims by trying a selective spacer shim between arbor and gauge block. (Chrysler)

marked .094 and the pinion is marked minus 2, add .002 in. (0.05 mm) to the thickness of the chosen .094 in. (2.38 mm) spacer. The correct spacer to place between the pinion gear and bearing will then be .094 + .002 = .096 in. (2.38 + 0.05 = 2.43 mm).

If a new pinion gear is being used in the same carrier and with the original bearings, adjust the original shim pack by the plus or minus amount marked on the pinion.

REMEMBER: WHEN PINION IS MARKED WITH A PLUS NUMBER, SUBTRACT THIS AMOUNT FROM THE SHIM PACK. WHEN A MINUS NUMBER IS USED, ADD THIS AMOUNT TO THE THICKNESS OF THE SHIM PACK. THE FORD TYPE PINION IN FIGS. 30-56 and 30-57 IS AN EXCEPTION. FOR THIS SPECIFIC SETUP, REVERSE THE PROCEDURE.

Install pinion after determining correct depth setting shim pack. Lubricate all parts before assembly. Parts must be clean and free of burrs.

PINION PRELOAD MUST BE CORRECT

To prevent the pinion gear from moving away from the ring gear under load, the pinion bearings must be properly preloaded.

If preload shims are used, Fig. 30-59, add or subtract shims until the preload is correct when the pinion flange nut is brought to the specified torque.

When the pinion flange retaining nut is torqued, turn the pinion shaft several turns to allow bearings to seat before checking preload.

When a collapsible spacer is used, Fig. 30-60, instead of shims to control preload, tighten the pinion flange retaining nut a little at a time with frequent checks for preload torque.

As the retaining nut is tightened, the spacer is forced to collapse, thus allowing the bearings to run under more pressure. If the preload torque is exceeded, a new collapsible spacer must be used. Never back the nut off to produce the proper preload.

See install pinion flange and adjust preload at the beginning of this chapter. Do not install the pinion oil seal until preload is correct.

INSTALLING DIFFERENTIAL CASE IN CARRIER (THREADED ADJUSTER TYPE)

Lubricate differential side bearings and place cups on bearings. Lubricate side bearing bores in the carrier to allow easy cup side movement.

Place case in the carrier. If the ring and pinion gearset is of the nonhunting type (any one pinion gear tooth contacts only a certain number of ring gear teeth), make certain that the marked ring and pinion teeth are meshed. See Fig. 30-69.

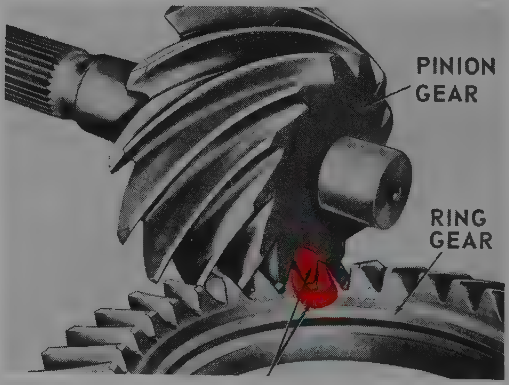


Fig. 30-69. Nonhunting gearset marking should be aligned when meshing ring to pinion gear. (Ford)

Hunting type gearsets (any one pinion gear contacts all ring gear teeth) will not be marked and may be meshed in any position.

Move the assembly in the bores until a small amount of backlash (play between ring and pinion gear) is present.

Install the threaded adjusters snugly against the bearing cups. Adjusters must be installed with about the same number of threads showing on the outside of each adjuster.

Install bearing caps so that marks are aligned. Insert cap fasteners and bring to correct torque. Check for smooth operation of adjusters as fasteners are torqued. If binding is experienced, remove and check for dirt, burrs, and nicks. Following full torquing, loosen fasteners and retorque to around 25 foot-pounds (33.90 N·m). Some manufacturers recommend loosening fasteners and then torquing ONE fastener on each cap to full torque.

Loosen the right-hand adjuster (or pinion side of ring gear) and tighten left-hand adjuster (on back side of ring gear) until no backlash is present. Rotate ring gear while tightening left-hand adjuster. Fig. 30-70 illustrates how the adjusters are moved by using spanner wrenches.

Tighten left-hand bearing cap fasteners to full torque. Turn right-hand adjuster in until left-hand bearing is in firm contact with left-hand adjuster. Loosen right-hand adjuster and retighten. At this point, the case bearings are just SNUG with NO end play or preload. There is NO backlash between ring and pinion.

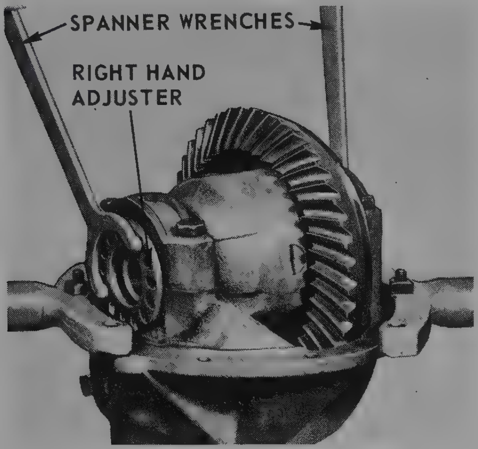


Fig. 30-70. Adjusters are easily moved with spanner wrenches. (Plymouth)

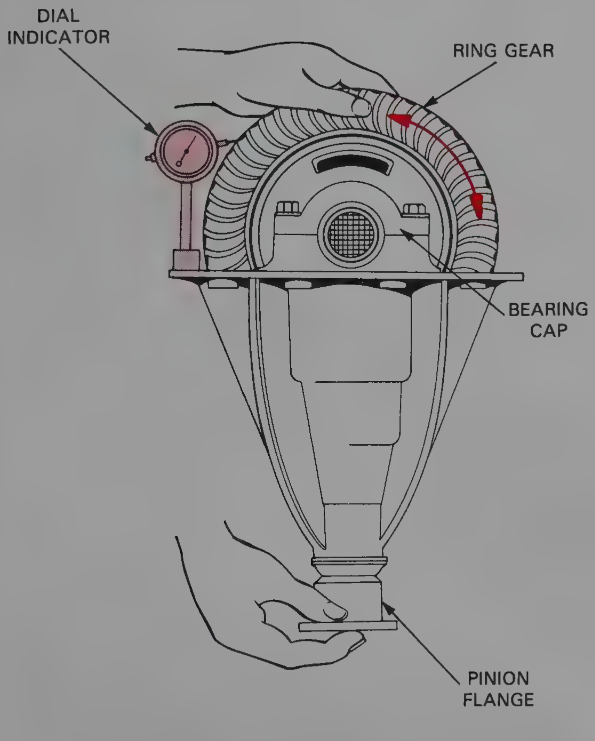


Fig. 30-71. Using a dial indicator to check ring gear-to-pinion gear backlash. Pinion is held firmly by grasping pinion flange. (Chevrolet)

Set up a dial indicator to check backlash. Indicator stem must be in line with direction of tooth travel. Look at Fig. 30-71.

After bringing the right-hand cap fasteners to full torque, turn the right-hand adjuster in two or three notches. This will preload the bearings and should give the specified backlash.

Check the backlash at four different spots around the ring. Leave ring in the position producing the smallest amount of backlash.

If backlash is as specified (around .006-.008 in. or 0.15-0.20 mm), insert the adjuster locks. Torque lock fasteners.

If backlash varies at the different points more than specified allowable variation (around .002 in. or 0.05 mm), check the ring gear for runout. If necessary, ring must be removed, cleaned, reassembled, and rechecked. Check case flange runout also, Fig. 30-72.

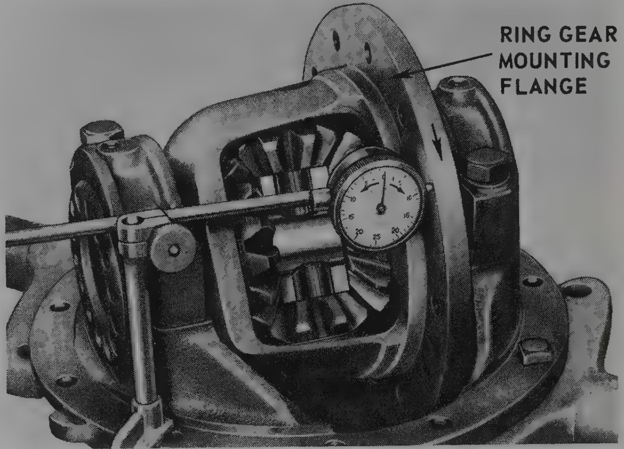


Fig. 30-72. Using a dial indicator to check ring gear mounting flange runout. (Dodge)

If backlash is not quite as specified, loosen one adjuster and tighten the other until backlash is correct. BEARING CAP FASTENERS MUST BE AT FULL TORQUE DURING THESE ADJUSTMENTS.

When moving the adjusters, move the adjuster that is being loosened TWO notches. Move the adjuster that is being tightened ONE notch. Then TIGHTEN THE ADJUSTER THAT WAS LOOSENED ONE NOTCH. This procedure assures that solid contact is made. It will prevent loosening in service.

Another method, sometimes specified for preloading differential side bearings, involves bringing the adjusters up so that no end play exists in the bearings. With no backlash between ring and pinion, a dial indicator is used to measure the carrier spread as the right-hand adjuster is tightened. When the carrier spread (distance between side bearing bores being increased due to bearing preloading) reaches the specified amount, the backlash should be close to specifications. If not, adjust by loosening one adjuster and tightening the other.

INSTALLING DIFFERENTIAL CASE IN CARRIER — SHIM PRELOAD ADJUSTMENT

Clean side bearing carrier bores. Lubricate bearings. Install cups. If old bearings are being used, use the original shim packs. Place shims on each end of bearing cups. Start case into carrier bores, Fig. 30-73.

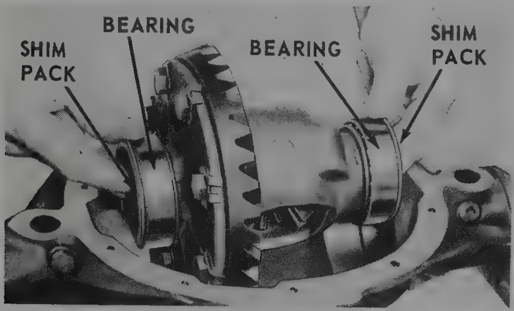


Fig. 30-73. Installing differential case. Note shim pack on end of each bearing.

If a new case, new carrier, or new bearings are used, the original shim packs will not guarantee the correct preload. In these instances, it will be necessary to determine the proper thickness shim pack.

In general, the selection of shims involves placing enough shims or spacers on each side to remove all side play (just snug, no preload). Refer to Fig. 30-74.

The manufacturer will usually specify a certain thickness spacer to place on one side to start with. This will aid in having the ring and pinion backlash within workable measurements when the side play is removed.

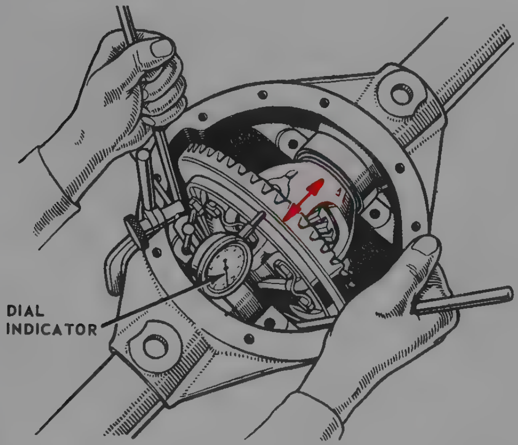


Fig. 30-74. Checking side play in differential case bearings. Add shims until backlash just disappears.

Shims may then be moved from one side to the other until the backlash is correct. See Fig. 30-75.

When the backlash is correct (check in four places at 90 deg. intervals around ring gear) and with no existing end play or preload, add two shims of equal thickness, one on each side. Use thickness as specified.

Use a carrier spreader, if needed, to permit installing the preload shims. Lubricate shims and avoid undue pounding. Light tapping on the shims, with a soft hammer, is permissible.

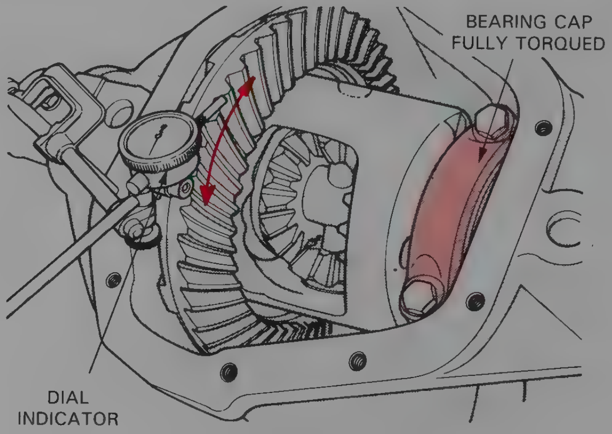


Fig. 30-75. Checking backlash between ring and pinion gears. Caps should be in place and fully torqued. (Chrysler)

There are some differential assemblies that place the side bearing shims between the carrier and the bearing inner cone. Look at Fig. 30-76.

Some production side bearing spacers cannot be reused. They must be replaced with steel service spacers and shims.

Some manufacturers specify that a specific preload adjustment check be made by using a torque wrench on one side of the ring gear fasteners or on the pinion shaft.

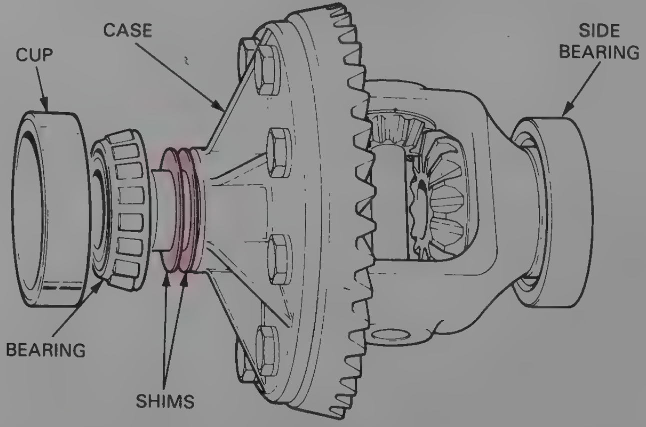


Fig. 30-76. This differential carrier uses shims between case and side bearing cones. (British-Leyland)

When preload and backlash adjustments are as specified, recheck the torque on the bearing cap fasteners. Rap top of fasteners with a hammer and retorque.

TOOTH CONTACT PATTERN

The relationship between the ring and pinion gears must be such that a desirable contact pattern is produced.

To check the contact pattern, (preload and backlash must be correct) cover all the ring gear teeth with a light coating of hydrated ferric oxide or some other suitable compound. Some new gear sets come with a special compound for this purpose. Apply to the teeth with a reasonably stiff paint brush. See Fig. 30-77.

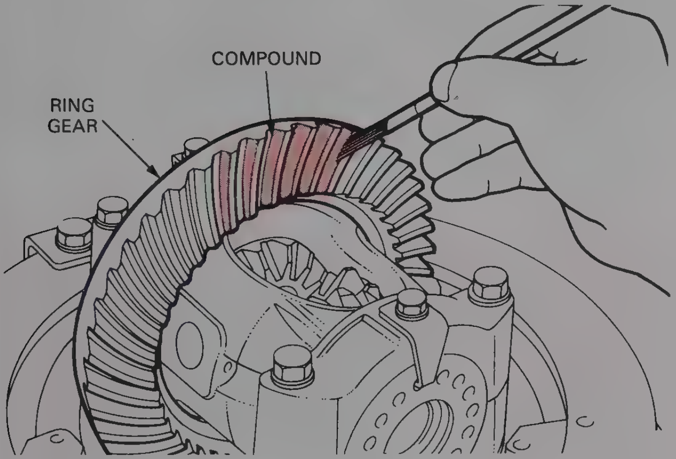


Fig. 30-77. Painting ring gear with hydrated ferric oxide compound. Coat both sides of each tooth so a drive and coast tooth contact pattern can be obtained. (Chrysler)

Using a wrench, turn the pinion shaft in the normal forward drive direction while creating a drag on the ring gear. The mechanic, in Fig. 30-78, is using a brass drift to bind the ring gear. Continue turning the pinion until the ring gear has made one full turn. This will produce a DRIVE (pinion driving ring) contact pattern, Fig. 30-78.

Turn the pinion in the opposite direction, while binding the ring, to produce a COAST (ring drives pinion) pattern.

There is no exact pattern that must be formed. The pattern shape varies depending upon gear set design, wear, and load.

In general however, the pattern (contact area) should be even around the ring. Uneveness indicates excessive ring runout.

The DRIVE pattern should be centrally located between the top and bottom of the tooth. It can be somewhat closer to the toe. Under increased loading, the pattern spreads out and tends to move towards the heel of the tooth. When the point of heavy loading is reached (pulling hills or rapid acceleration), the pattern may extend almost the full distance from toe to heel. The DRIVE SIDE of a ring gear tooth is the CONVEX side. The COAST side of a ring gear tooth is the CONCAVE side. Note the gear tooth nomenclature in Fig. 30-79.

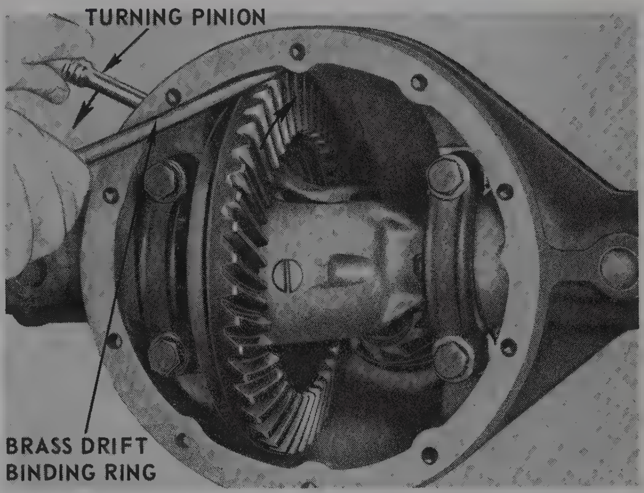


Fig. 30-78. Cranking pinion while binding ring gear to produce a drive pattern.

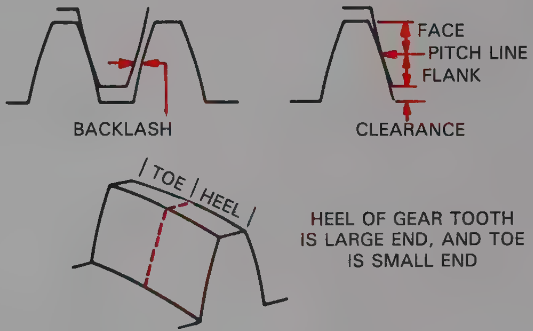


Fig. 30-79. Gear tooth nomenclature.

The COAST pattern should also be centralized between top and bottom of the tooth. It may be a little longer and closer to the toe.

Examine the pattern closely for the presence of thin, hard pressure lines that indicate an area of narrow contact that will produce unusually high localized pressure. Such lines should not be present.

Typical ACCEPTABLE DRIVE and COAST patterns are pictured in A, B, and C, Fig. 30-80. UNACCEPTABLE patterns, D, E, F, and G, are also shown.

A HEEL contact pattern is caused by excessive backlash. It is corrected by moving the ring towards the pinion, D, Fig. 30-80. TOE contact indicates insufficient backlash. To correct, move the ring away from the pinion, E. FACE contact indicates the pinion is set too

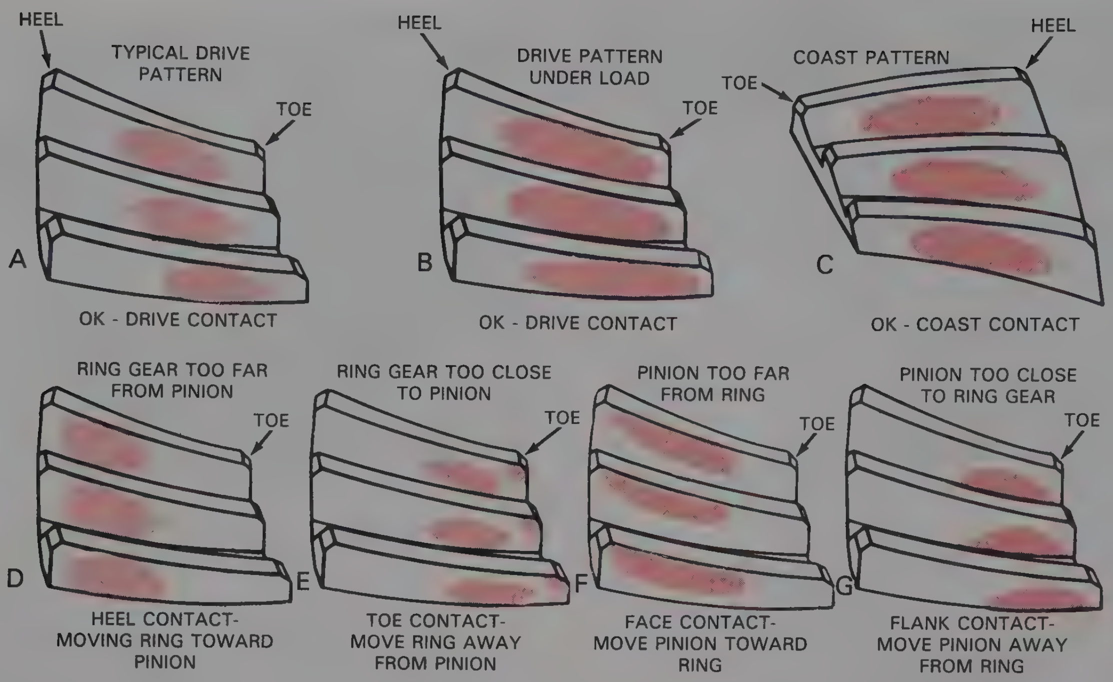

HEEL
TYPICAL DRIVE PATTERN
TOE
A
OK - DRIVE CONTACT
HEEL
DRIVE PATTERN UNDER LOAD
TOE
B
OK - DRIVE CONTACT
HEEL
COAST PATTERN
TOE
C
OK - COAST CONTACT
RING GEAR TOO FAR FROM PINION
TOE
D
HEEL CONTACT-MOVING RING TOWARD PINION
RING GEAR TOO CLOSE TO PINION
TOE
E
TOE CONTACT-MOVE RING AWAY FROM PINION
PINION TOO FAR FROM RING
TOE
F
FACE CONTACT-MOVE PINION TOWARD RING
PINION TOO CLOSE TO RING GEAR
TOE
G
FLANK CONTACT-MOVE PINION AWAY FROM RING

Fig. 30-80. Typical ring gear tooth contact patterns.

far from the ring. To correct, move the pinion TOWARD the ring, F. FLANK contact requires moving the pinion AWAY from the ring gear, G, Fig. 30-80.

When moving either ring or pinion to correct the contact pattern, move in small amounts. Make certain that the bearings are properly preloaded, the cap fasteners fully torqued, and the backlash within specifications before rechecking pattern.

SPECIAL TRACTION DIFFERENTIAL

The limited slip (also called Sure Grip, No-Spin, Anti-Spin, Positive Traction) type of traction differential uses friction members (cone or disc clutch). When one wheel attempts to spin, driving force will still be applied to the nonspinning wheel by the differential.

In the conventional, nontraction differential, when one wheel spins, no driving force is applied to the other.

A traction differential, using a clutch pack on either side of axle side gears, is pictured in Fig. 30-81.

In the Sure Grip design, Figs. 30-81 and 30-82, two pinion shafts are used. Note that the ends of the shafts are wedge shaped. They operate in V-shaped ramps.

When a driving force is applied to the ring gear, the pinion shafts slide up the V-ramps and compress both clutch packs. This effectively provides a mechanical connection between both axles.

When rounding a corner, the outside axle turns faster than the inner axle. This causes the pinion shaft on the outer side to slide down its ramp. This releases the clutch pack on that side and allows normal differential action.

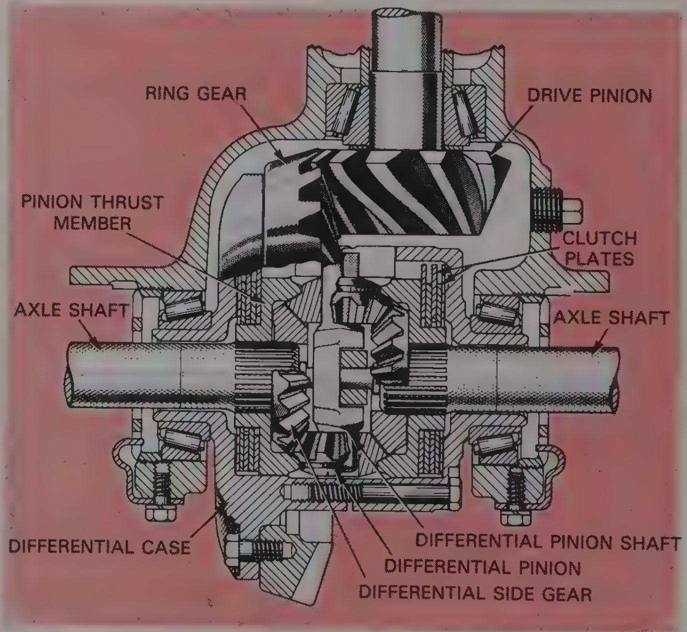

RING GEAR
DRIVE PINION
PINION THRUST MEMBER
CLUTCH PLATES
AXLE SHAFT
AXLE SHAFT
DIFFERENTIAL CASE
DIFFERENTIAL PINION SHAFT
DIFFERENTIAL PINION
DIFFERENTIAL SIDE GEAR

Fig. 30-81. Cross section view of Sure Grip type of differential.

If one wheel spins, the clutch pack on that side is released. The pack on the slower turning wheel causes it to remain clutched to the differential case. It will thus receive turning force despite differential action. Fig. 30-82 illustrates a cutaway view of the Sure Grip differential. Fig. 30-83 depicts a cross section view of a traction differential that has a preload spring instead of V-shaped ramps found in the Sure Grip type.

A somewhat different type of traction differential

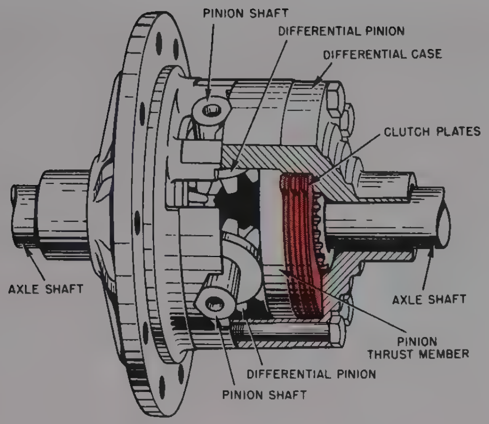

PINION SHAFT
DIFFERENTIAL PINION
DIFFERENTIAL CASE
CLUTCH PLATES
AXLE SHAFT
AXLE SHAFT
PINION THRUST MEMBER
DIFFERENTIAL PINION
PINION SHAFT

Fig. 30-82. Cutaway view of Sure Grip type differential. (Chrysler)

(Positive Traction) is illustrated in Fig. 30-84. This unit uses cone clutch brakes, one on each side of the axle side gears, to provide traction.

Normal differential action causes clutches to slip. When one wheel starts spinning, the slower moving axle still remains clutched to the differential case and will therefore receive some driving force.

Cone brakes are kept preloaded to the case by means of preload springs. The normal tendency for the side gears to move away from the pinions under load also increases the cone loading. See Fig. 30-84.

Another application of a traction differential is shown in Fig. 30-85. In this setup, a clutch pack is used only on one side. The pack is preloaded by the action of a Belleville clutch plate and a Belleville clutch disc. Additional loading is provided by the side gears attempting to move away from the pinions. See Fig. 30-85.

One particular positive action type traction differential uses a governor assembly. The purpose of the governor is to positively lock both rear axles (wheels) together when one wheel spins more than 100 rpm faster than the other during slow vehicle operation. Fig. 30-86 shows an exploded view of this unit.

Lockup takes place through the use of flyweights in

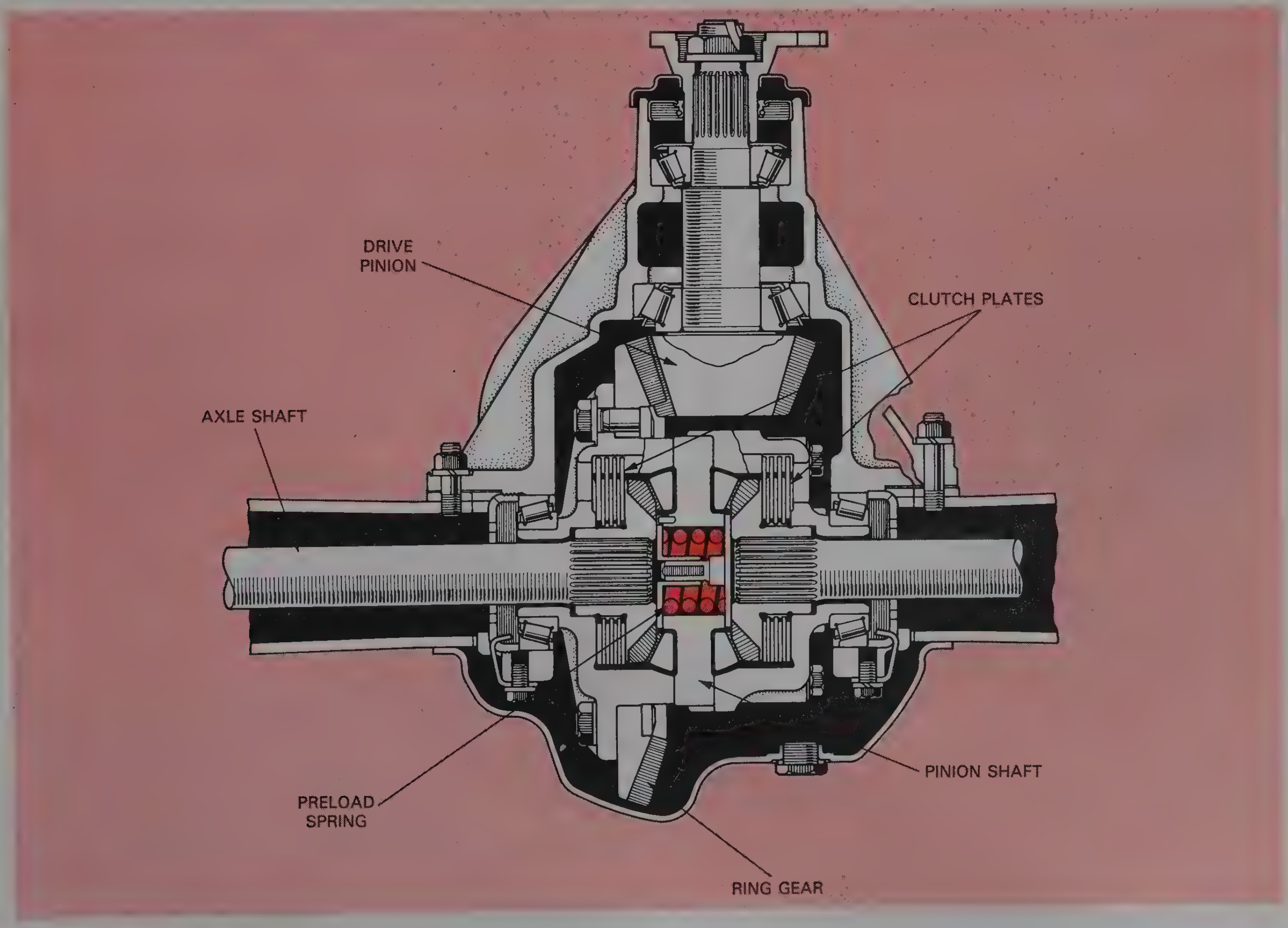

DRIVE PINION
CLUTCH PLATES
AXLE SHAFT
PRELOAD SPRING
PINION SHAFT
RING GEAR

Fig. 30-83. This limited slip traction type differential uses a single preload spring. Note clutch plates. (Toyota)

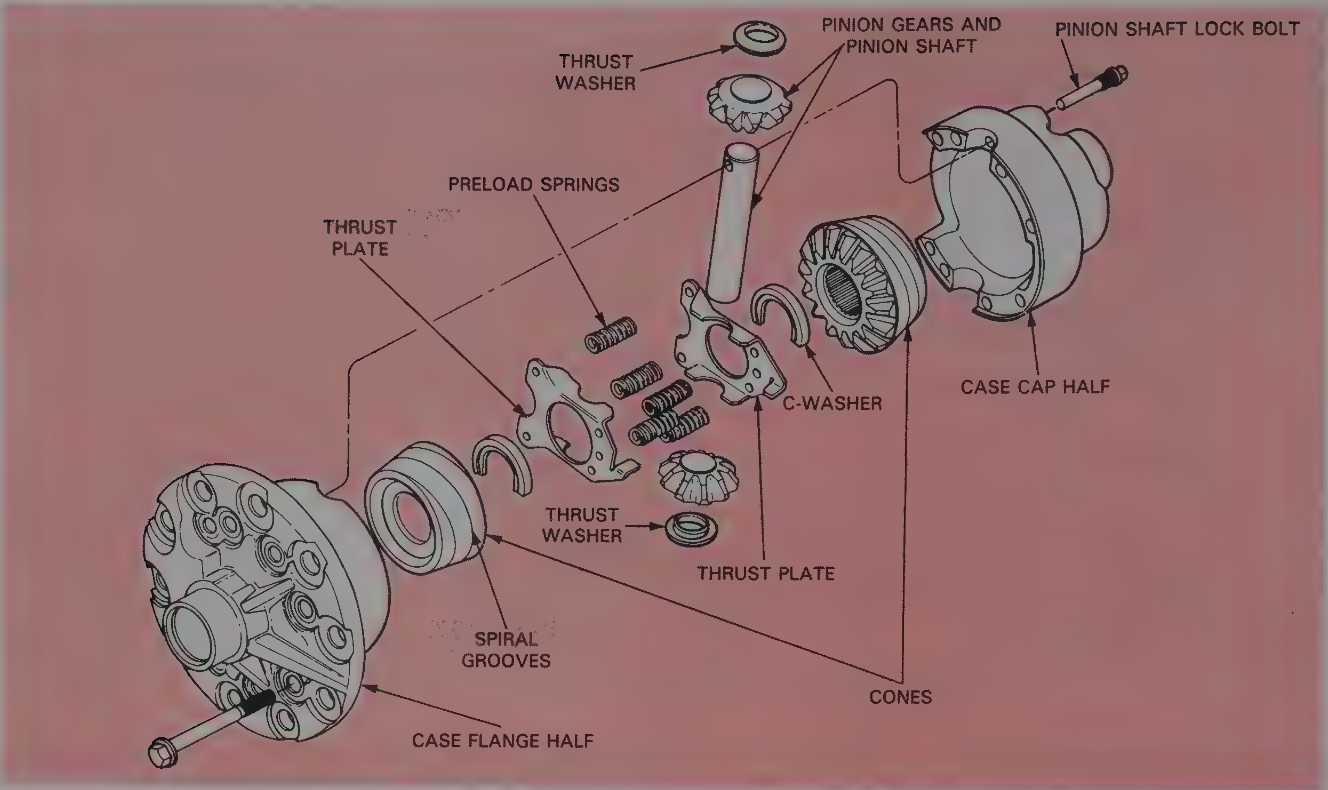

THRUST WASHER
PINION GEARS AND PINION SHAFT
PINION SHAFT LOCK BOLT
PRELOAD SPRINGS
THRUST PLATE
C-WASHER
CASE CAP HALF
THRUST WASHER
THRUST PLATE
SPIRAL GROOVES
CONES
CASE FLANGE HALF

Fig. 30-84. Exploded view of a cone type positive traction differential. Note spiral grooves on cones. These grooves provide lubrication passages. (Ford)

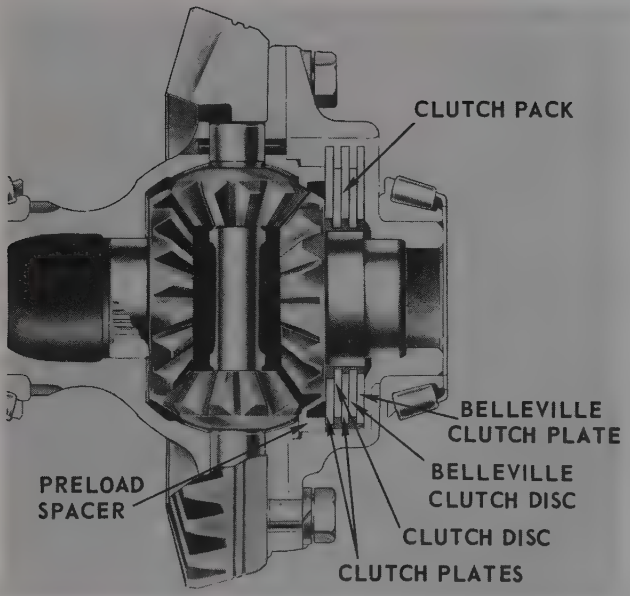

CLUTCH PACK
BELLEVILLE CLUTCH PLATE
BELLEVILLE CLUTCH DISC
PRELOAD SPACER
CLUTCH DISC
CLUTCH PLATES

Fig. 30-85. Traction type differential that uses a single clutch pack. Belleville clutch disc and plate are cup-shaped. When flattened out, they exert a spring effect on remainder of pack. (G.M.C.)

the governor, cam system, and the multiple-disc clutch units. The flyweights move outward to engage the latching bracket as one axle turns faster than the other. This retards the camform side gear. In turn, this compresses the multiple-disc clutch unit, locking one side gear to the case. Equal driving torque is then transmitted to each wheel. When axle (wheel) speed difference drops below 100 rpm or road speed of vehicle is 20 mph (32 km/h) or faster, the differential operates as a standard (nonpositive traction) type.

Service of this unit is basically the same as other types using clutch plates. Follow maker's recommendations.

TESTING TRACTION DIFFERENTIAL ACTION

Traction type differential action may be checked by raising ONE wheel free of the floor. Place the transmission in neutral and block the wheel remaining in contact with the floor. Release parking brake.

Use an adapter similar to that in Fig. 30-87 to provide a means of attaching a torque wrench to the raised wheel. Wrench head must be in the CENTER of the wheel.

Turn the wheel and note the amount of torque required to keep the wheel moving. Check against specifications. Torque specifications will vary depending upon design. Some positive action differential units can be tested while they are out of the axle housing. They can be held in a vise with a special tool and rotated (in direction of normal travel) with a torque wrench. See Fig. 30-88. The initial break-away (when unit begins

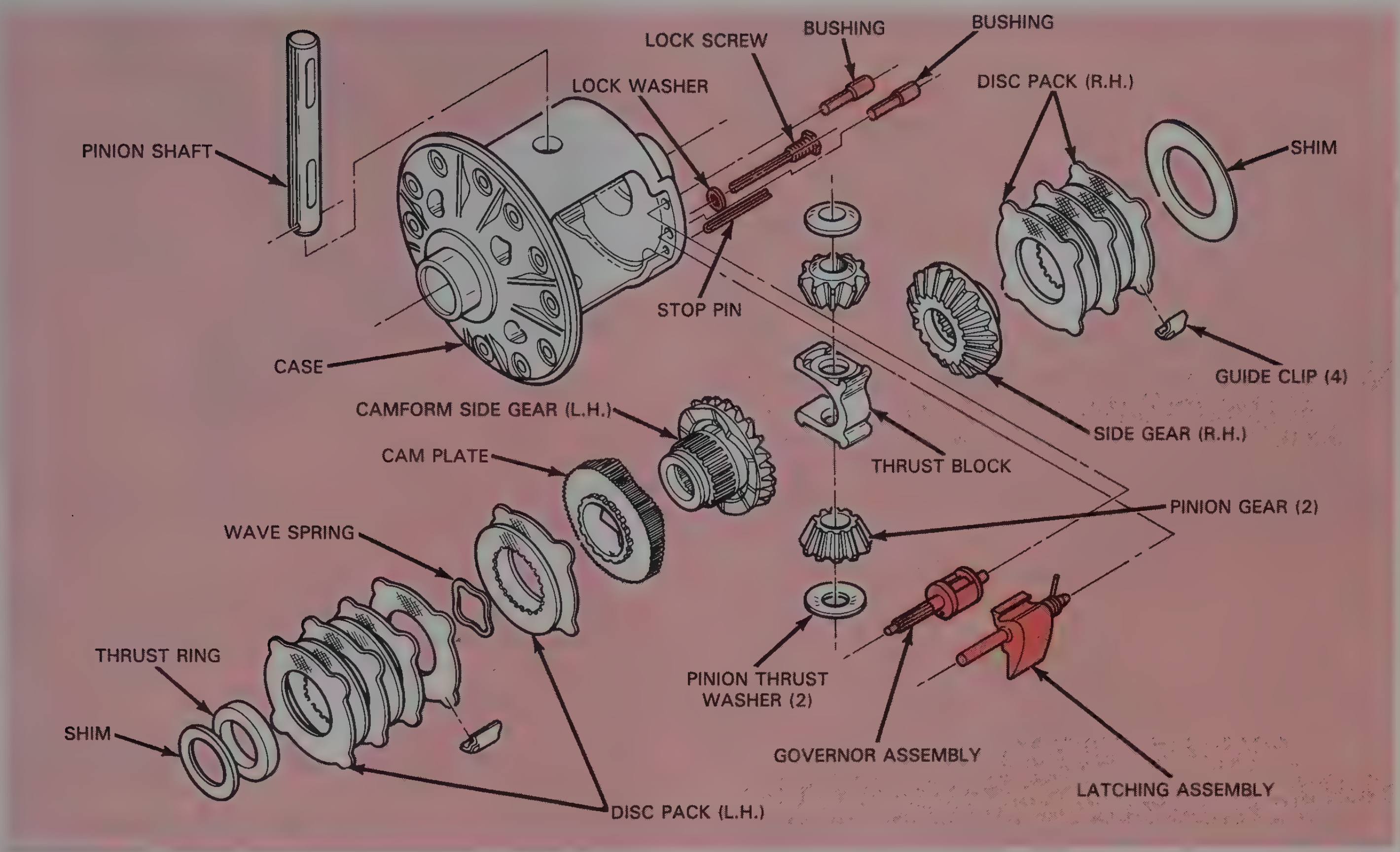

PINION SHAFT
LOCK SCREW
BUSHING
BUSHING
LOCK WASHER
DISC PACK (R.H.)
SHIM
STOP PIN
CASE
GUIDE CLIP (4)
CAMFORM SIDE GEAR (L.H.)
SIDE GEAR (R.H.)
CAM PLATE
THRUST BLOCK
PINION GEAR (2)
WAVE SPRING
THRUST RING
PINION THRUST
WASHER (2)
SHIM
GOVERNOR ASSEMBLY
LATCHING ASSEMBLY
DISC PACK (L.H.)

Fig. 30-86. Exploded view of a positive traction differential. Note governor assembly. (Chevrolet)

to slip under force) torque is then recorded. Use manufacturer's torque reading for your specific unit.

Some traction differentials use only gears instead of cones or clutch plates. They generally do not require special lubricants.

TRACTION DIFFERENTIAL SERVICE

Other than the clutch packs, cone brakes, and springs that make up the limited slip action, service on the trac-

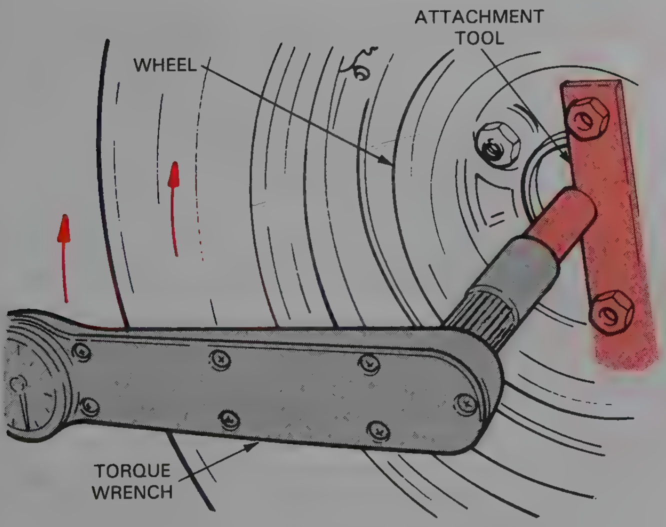

ATTACHMENT
TOOL
WHEEL
TORQUE
WRENCH

Fig. 30-87. Checking traction differential action by measuring torque required to turn raised (off ground) wheel. Note attachment tool to connect and center torque on wheel. (Ford)

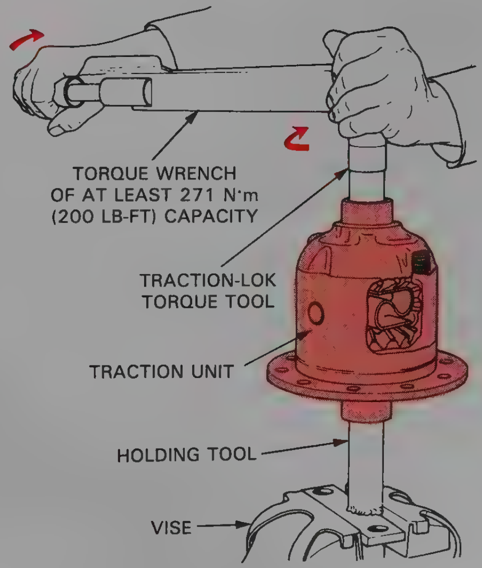

TORQUE WRENCH
OF AT LEAST 271 N·m
(200 LB-FT) CAPACITY
TRACTION-LOK
TORQUE TOOL
TRACTION UNIT
HOLDING TOOL
VISE

Fig. 30-88. Testing a traction differential unit out of carrier. Use proper tools and mounting procedures for an accurate reading. (Ford)

tion differential is much like that for the conventional unit already discussed.

If the differential case is split (made in two pieces), make certain the two halves are marked before disassembly. See Fig. 30-89.

Following disassembly, clean and inspect all parts. If brake cones will be reused, do not reverse positions. IF ONE HALF OF THE CASE IS DAMAGED, REPLACE BOTH HALVES.

During reassembly, lubricate all parts thoroughly with special traction differential lubricant. Use the axles to align the side gears and cone brakes, or pinion thrust blocks, while the case is bolted together.

Install differential in the axle housing. If the axle end thrust blocks are of the type that can fall out of position, check that they are in place before installing the axles. See Fig. 30-81.

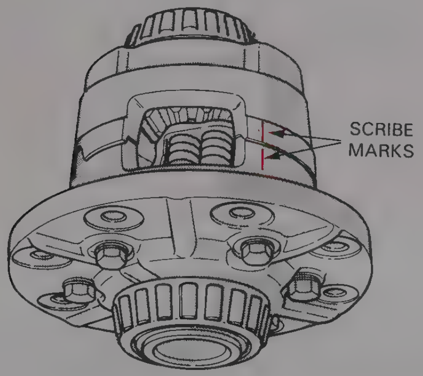


Fig. 30-89. Traction type differential case markings. Align scribe marks when reassembling halves. (Chrysler)

DRIVE AXLE LUBRICATION

For conventional differentials, the use of a hypoid or a multipurpose gear lubricant is generally specified. Use recommended viscosity.

Most traction type differentials require a special lubricant. NEVER USE ANYTHING BUT THE SPECIFIED OIL.

Maintain the oil level in the housing so that, if checked warm, the level is in line with the bottom of the filler hole. If cold, level can be up to 1/2 in. (12.70 mm) below hole. WIPE OFF FILLER PLUG AND SURROUNDING AREA BEFORE PLUG REMOVAL. WIPE OFF FILLER GUN NOZZLE. UNDER NO CIRCUMSTANCES MUST ANY FOREIGN MATERIAL ENTER THE HOUSING. See Fig. 30-90.

KEEP VENT OPEN

The axle housing is vented by means of a small hole, a tiny capped pipe, or hose. The vent prevents a buildup of pressure within the housing as the lubricant warms up. Make certain the vent is open.

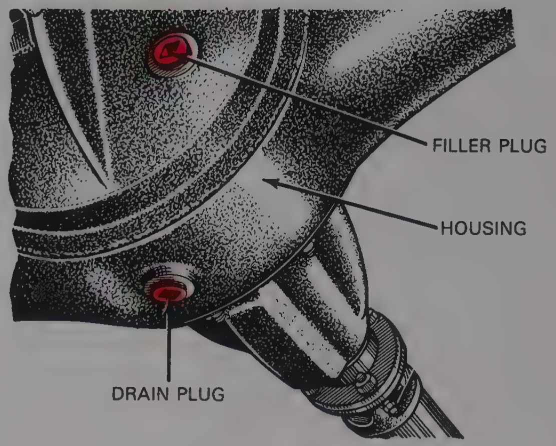


Fig. 30-90. Wipe off filler plug, surrounding area, and filler gun nozzle to prevent entry of foreign material into housing.

HOUSING ALIGNMENT

One method of checking housing alignment is shown in Fig. 30-91. The flanges on the axle ends must be CLEAN and free of burrs. Straight edges must be STRAIGHT and held in firm contact with the flanges during measurement. See manufacturer's specifications for allowable misalignment. Check in horizontal and vertical positions.

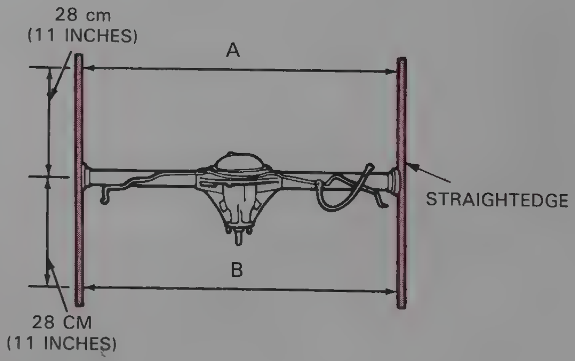


Fig. 30-91. Checking housing alignment. For this particular housing, the difference between measurement A and B should not exceed 3/32 in. (2.38 mm). Check in a vertical as well as horizontal plane. (American Motors)

SUMMARY

The typical drive axle assembly is of semifloating design. Axles are retained in the housing by using a retainer plate or by C-locks.

Before road testing, check lubricant level, tire pressure, and tread pattern. Check action during drive, cruise, float, and coast conditions.

Road surface, tire tread, front wheel bearings, transmission, and other factors can make noises easily mistaken for drive axle problems. Check carefully before pulling axle down.

Check bearing preload. Scribe a line on pinion shaft, retaining nut, and flange before loosening retaining nut. Hold companion flange with special wrench while loosening flange nut. Use puller to remove flange.

Clean pinion seal recess. Soak new seal if required. Coat outer diameter of new seal with cement. Install, lip in, to correct depth.

Inspect pinion flange for nicks and burrs. Lubricate before installation. Draw flange on with nut. Never pound on the pinion flange or pinion shaft. Tighten pinion flange nut as required. If preload is exceeded, install a new collapsible spacer (where used).

Pull axles by removing retainer plates or inner end C-locks. On front-wheel drive units, remove universal joints and/or spindle assembly. Use a slide hammer puller on conventional axles. Do not disturb backing plate unless necessary. If backing plate must be pulled, disconnect brake line.

If an axle was broken or if other damage occured, flush housing thoroughly. Check axle for twists and bends.

Do not wash sealed wheel bearings. Always install new oil seals following axle removal. Notch bearing retainer rings to remove.

When pressing new wheel bearings into place, apply pressure to the inner race only. Press a new retaining ring into firm contact with the bearing. Do not press ring and bearing on at the same time. Bearing must face in the correct direction and must be pressed on to the proper position.

When installing axles, do not damage the seals.

Retainer plate must be positioned so that the oil drain hole will function.

Where axle and end play shims are used, install in their original positions. Check axle end play.

Where a tapered end axle is used, make certain the drive key is in place when hub is attached to axle. Use a new cotter pin to secure hub retaining nut.

Some carriers are removable, others are an integral part of the housing.

Mark differential case bearing adjusters and bearing caps before disassembly. Check backlash and tooth contact pattern before removing case.

Use a puller or pry case out of carrier. Mark and save all shims. A spreader may be required. Generally, do not spread housings more than .020 in. (0.51 mm).

Clean and inspect differential case and parts. Replace as needed. When case side bearings must be replaced, use new outer cups. Ring and pinion must be replaced as a matched pair. Ring and pinion must have matching numbers. Mark ring and pinion gears before disassembly if they are of the nonhunting type.

Check ring gear flange for runout. Attach ring gear with special fasteners. Contact surfaces of ring and pinion must be spotless. Lubricate ring gear fasteners or coat with recommended liquid adhesive before assembly. Fasteners must be a snug fit in ring and flange.

When removing pinion shaft, mark and save shims. Do not damage bearing counterbore during removal of pinion outer races.

Set proper pinion depth by using a special setting gauge. When using a new drive pinion, correct the depth setting by allowing for the plus or minus amount marked on the pinion. Shims must be clean and of the thickness to provide exact pinion depth.

When installing pinion, preload must be as specified. Use a new seal.

Before installing differential case, lubricate entire assembly thoroughly. If the ring and pinion gear set is of the nonhunting type, mesh the marked teeth during case assembly.

Adjust case side bearing preload as specified. Check ring and pinion backlash. Check ring and pinion tooth contact pattern by coating ring gear with a special compound. Load ring gear and turn pinion until ring makes one full turn. Do this in both drive and coast directions.

Contact pattern should be centralized between bottom and top of tooth. Pattern may be slightly toward the toe.

Correct faulty pattern by adjusting pinion in or out by moving the ring toward or away from the pinion.

Traction type differentials utilize clutch packs or cone brakes to provide power to both axles, even when one wheel is spinning. Some units are equipped with governors.

Traction differentials may be tested in the vehicle by measuring the torque required to turn the raised wheel. The other wheel must contact the floor. The transmission and/or transfer case must be in neutral, with emergency brake off.

Lubricate all traction differential parts with recommended lubricant upon assembly. Fill differential housing to within 1/4 to 1/2 in. (6.35 to 12.70 mm) of the filler plug or as recommended by the manufacturer. Use multipurpose gear lubricant for conventional differentials and a special lubricant for traction type units if required. Do not allow dirt to enter the housing when checking lubricant level or when filling.

Axle vent must be open.

PROBLEM DIAGNOSIS

PROBLEM: NOISE DURING STRAIGHT AHEAD DRIVING

Possible Cause	Correction
1. Insufficient lubricant.	1. Fill housing to correct level.
2. Improper lubricant.	2. Drain. Flush and fill with correct lubricant.
3. Differential case bearings worn.	3. Replace bearings.
4. Drive pinion shaft bearings worn.	4. Replace pinion bearings.
5. Ring and pinion worn.	5. Replace ring and pinion.
6. Excessive backlash.	6. Adjust backlash.
7. Insufficient backlash.	7. Adjust backlash.
8. Excessive ring and pinion backlash.	8. Adjust backlash.
9. Insufficient ring and pinion backlash.	9. Adjust backlash.
10. Pinion shaft or differential case bearings not preloaded.	10. Preload as specified.
11. Excessive ring gear runout.	11. Remove ring. Clean. Check flange runout. Reinstall and check. Replace ring or case as needed.
12. Ring gear fasteners loose.	12. Torque fasteners.
13. Ring and pinion not matched.	13. Install a matched set.
14. Differential case bearing cap fasteners loose.	14. Torque fasteners.
15. Warped housing.	15. Replace housing.
16. Pinion shaft companion flange retaining nut loose.	16. Torque nut.
17. Tooth (ring and pinion) contact pattern incorrect.	17. Adjust as needed.
18. Loose wheel.	18. Tighten wheel lugs.
19. Wheel hub loose on tapered axle.	19. Inspect, if not damaged, torque retaining nut.
20. Wheel hub key (on tapered axle) sheared.	20. Install new key.
21. Wheel (axle) bearing worn.	21. Replace bearing.
22. Bent axle.	22. Replace axle.
23. Wheel hub or axle keyway worn.	23. Replace axle or hub as needed.
24. Dry pinion shaft seal.	24. Replace seal.
25. Loose universal joint mounting.	25. Tighten.
26. Damaged universal joint.	26. Repair or replace.
27. Worn or broken front-wheel drive front suspension parts.	27. Repair or replace as necessary.
28. Worn or broken transaxle unit.	28. Repair or replace as needed.

PROBLEM: NOISE WHEN ROUNDING A CURVE

Possible Cause	Correction
1. Differential pinion gears worn or broken.	1. Replace gears.
2. Differential pinion shaft worn.	2. Replace pinion shaft.
3. Axle side gears worn or broken.	3. Replace side gears.
4. Excessive axle side gear or pinion gear end play.	4. Install new thrust washers or replace case and/or gears.
5. Excessive axle end play.	5. Adjust end play.
6. Improper type of lubricant.	6. Drain. Flush and fill with correct lubricant.
7. Loose or broken suspension parts (front-wheel drive).	7. Repair or replace parts as needed.
8. Loose or broken universal joints.	8. Tighten or replace joints.

PROBLEM: CLUNKING SOUND WHEN ENGAGING CLUTCH, ACCELERATING, OR DECELERATING

Possible Cause	Correction
1. Excessive ring and pinion backlash.	1. Adjust backlash.
2. Excessive end play in pinion shaft.	2. Preload bearings.
3. Axle side gears and pinions worn.	3. Replace.
4. Differential bearings worn.	4. Replace bearings.
5. Side gear thrust washers worn.	5. Replace thrust washers.
6. Differential pinion shaft loose in case or pinions.	6. Replace pinion shaft, gears, or differential case.
7. Axle shaft splines worn.	7. Replace axle.
8. Wheel hub or axle keyway worn.	8. Replace hub or axle.
9. Loose wheel or hub.	9. Tighten fasteners.
10. Loose or broken universal joints.	10. Tighten or replace damaged joints.

PROBLEM: LOSS OF LUBRICANT

Possible Cause	Correction
1. Breather clogged.	1. Open breather.
2. Worn seals.	2. Install new seals.
3. Carrier-to-housing or inspection cover loose.	3. Tighten fasteners.

Problem: Loss of Lubricant continued

Possible Cause	Correction
4. Carrier or inspection cover gasket damaged.	4. Install new gasket or sealer.
5. Lubricant level too high.	5. Lower to proper level.
6. Wrong type of lubricant.	6. Drain. Flush and install correct lubricant.
7. Porous housing (standard and transaxle).	7. Repair or replace housing.
8. Stripped fill plug threads.	8. Repair or replace as needed.
9. Cracked housing (standard and transaxle).	9. Repair or replace housing.

PROBLEM: NOISES THAT MAY BE CONFUSED WITH DRIVE AXLE ASSEMBLY

Possible Cause	Correction
1. Low tires.	1. Inflate to proper pressure.
2. Road surface.	2. Test on different road.
3. Transmission.	3. Check transmission.
4. Bent propeller shaft.	4. Replace shaft.
5. Loose U-joints.	5. Install new U-joints.
6. Engine.	6. Check engine.
7. Front wheel bearings.	7. Replace bearings.
8. Tire tread.	8. Inflate TEMPORARILY to 50 psi (34.5 kPa) for road test only.
9. Dragging brakes.	9. Adjust brakes.
10. Excessive front wheel end play (disc brake pads rub on disc when rounding corners).	10. Adjust wheel bearings.

PROBLEM: OVERHEATING

Possible Cause	Correction
1. Wrong type of lubricant.	1. Drain. Flush and fill with correct lubricant.
2. Insufficient lubricant.	2. Bring to proper level.
3. Overloading (pulling heavy trailer).	3. Reduce load.
4. Gears worn.	4. Replace gears.
5. Bearing preload too great.	5. Preload as specified.
6. Insufficient backlash between ring and pinion.	6. Adjust backlash.

KNOW THESE TERMS

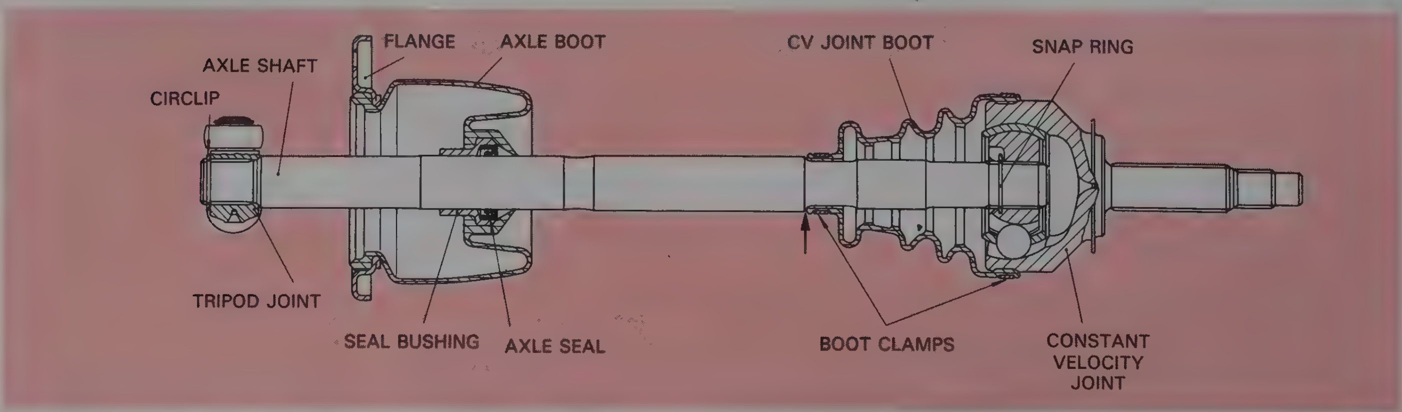
Drive axle, Semifloating, Three-quarter floating, Full-floating, Axle housing, Pinion shaft, Pinion, Ring gear, Carrier bearing, Bearing cap, Axle side gear, Bearing preload, Pinion flange, Collapsible preload spacer, Flanged end axle, Axle retainer, Tapered end axle, Axle end play, Wheel hub, Integral carrier, Backlash, Housing spreader, Pinion gear, Hunting gearset, Nonhunting gearset, Ring gear runout, Ring gear centerline, Tooth contact pattern, Coast pattern, Drive pattern, Traction differential, Belleville clutch, Brake cones.

QUIZ - Chapter 30

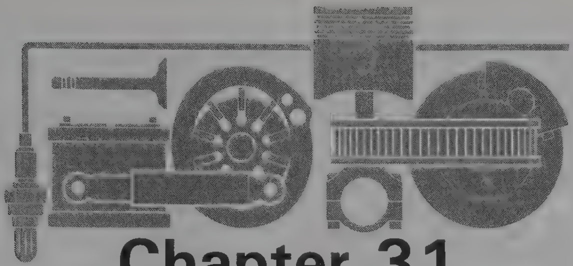
1. Most drive axle designs are of the:
   a. Full-floating.
   b. Three-quarter floating.
   c. Semifloating.
   d. Nonfloating.
2. Axles are retained in the housing by using a ____________ plate or by using ____________ on the axle inner ends.
3. List three things that can make noises that can be mistaken for drive axle problems.
4. Before road testing, check the ________________ ______________ in the axle housing.
5. Road test for proper operation during __________, __________, __________, and coast conditions.
6. Bearing noises are noticeable over a wider speed and operational condition range than gear noises. True or False?
7. Before removing pinion flange, check the bearing ______________.
8. Hold the pinion flange with a pipe wrench while loosening the retaining nut. True or False?
9. When replacing the pinion flange, if it goes on hard:
   a. Drive on with a soft hammer.
   b. Use a puller.
   c. Heat flange.
   d. Heat pinion shaft.
10. Pinion seal must be installed with ____________ ____________ on its OD. It must be driven in ____________ and to the proper ____________. Seal lip must face ____________.
11. When tightening pinion flange retaining nut on installations using a collapsible spacer, what must be done if the preload is exceeded?

   a. Install a new spacer.
   b. Back off nut until preload is correct.
   c. Back off nut past correct preload and tighten until preload is correct.
   d. Leave preload alone.

12. The brake backing plate must always be removed before pulling an axle. True or False?
13. Whenever an axle has broken or other damage has incurred, always ______________ the housing thoroughly.
14. Always install a new oil seal whenever an axle has been removed. True or False?
15. Axle wheel bearing retainer rings may be removed from the axle after:
    a. Heating.
    b. Chilling.
    c. Notching with a chisel.
    d. Cutting with a torch.
16. Install wheel bearing and retainer ring on the axle at the same time. True or False?
17. When removing or installing bearings, use the proper equipment to protect against flying parts as bearings can explode. True or False?
18. The wheel hub on a tapered end axle is kept from turning by a ______________.
19. Before removing the differential case from the carrier, ______________ the ______________ and adjusters to insure correct installation.
20. Differential side bearing shims may be mixed and used on either side. True or False?
21. When expanding the housing to remove the case, never expand beyond ____________.
22. Ring and pinion gears must be replaced as matched sets. True or False?
23. When attaching the ring gear to the case flange, use:
    a. Any fasteners of the right size.
    b. Special fasteners for this purpose.
    c. All new fasteners.
    d. Fasteners with split lock washers.
24. Pinion depth is adjusted by placing shims between the __________ and case or between __________ and __________ __________.
25. Pinion depth can be set satisfactorily by measuring from the pinion gear to the axle centerline with an accurate ruler. True or False?
26. A pinion gear marked +2 must be shimmed so that it will operate .002 of an inch closer to the ring gear centerline than a pinion marked O. True or False?
27. In the hunting type of ring and pinion gear set, any one tooth on the pinion will contact all teeth on the ring. True or False?
28. When checking backlash between ring and pinion, place the dial indicator stem against one of the ______________ gear teeth.
29. Proper ring and pinion tooth contact pattern is important. The pattern should generally be:
    a. Centralized on the tooth.
    b. Centralized between top and bottom of the tooth but closer to the toe.
    c. Centralized between top and bottom of the tooth but closer to the heel.
    d. Near the top of the tooth and extending over the entire length.
30. Tooth contact pattern is adjusted by moving either the ____________ or the ____________.
31. Traction type differential units should always be lubricated with regular multipurpose gear lubricant. True or False?
32. An axle housing alignment check may be performed by placing a ____________________ on each housing end flange and then measuring between them.
33. Front-wheel drive axles use ________________ ________________ to allow wheel movement.
34. Front-wheel drive axles can be of a one or two-piece design. True or False?
35. Front-wheel drive axle length changes (during suspension travel) are permitted by the use of ____________ ____________ and/or special ____________ ____________.



Cross section of a drive axle. Study the construction carefully. (Yugo)



Chapter 31

BRAKE SERVICE

After studying this chapter, you will be able to:

☐ Explain drum brake construction, operation, and service.
☐ Summarize disc brake construction, operation, and service.
☐ Explain the operation and service of power brakes.
☐ Describe master cylinder operation, construction, and service.
☐ Diagnose common brake system problems.

BRAKE SYSTEM OPERATION

The hydraulic brake system uses a master cylinder to develop hydraulic pressure. The master cylinder may be power (vacuum or hydraulic) assisted.

Pressure is transmitted to each caliper and wheel cylinder via a solid column of brake fluid in double-wrapped, coated steel tubing and flex hoses.

When master cylinder is in released position, Fig. 31-1, only a low static pressure remains (drum brakes only) in the lines. The brake shoe retracting springs pull the shoes away from the brake drum and force the wheel cylinder pistons inward. This action causes fluid to flow through the lines toward the master cylinder. The fluid will lift the check valve from its seat and flow into the master cylinder reservoir.

When pressure in the lines has dropped to the point where it is less then the force developed by the check valve spring, the check valve will be returned to its seat. This maintains residual line pressure. Many systems do not use residual check valves. They depend on wheel cylinder cup design or cup expanders to exclude air from the system.

Fig. 31-1 shows the braking system (one wheel assembly only) when brakes are released. Note that the master cylinder piston is released to the point where the primary cup clears the compensating port. This allows fluid to move into the reservoir.

When the brake pedal is depressed, the master cylinder piston is forced into the cylinder. As soon as the primary cup passes the compensating port, the fluid ahead of the piston is trapped. Any further piston movement will force the fluid to flow through the lines. This moves the wheel cylinder pistons outward until the brake shoes contact the drum. Any increase in brake pedal pressure beyond this point will cause a corresponding increase in shoe-to-drum contact. Fig. 31-2 shows the system with brakes being applied.

When the brake pedal is released, the brake shoe retracting springs force fluid to flow backward into the master cylinder. Tiny holes in the piston prevent vacuum action that could draw air into the cylinder. The holes also permit instant piston release until the check valve can move from its seat. The primary cup lips are forced away from the cylinder wall by the passage of fluid through tiny bleeder holes in the head of the piston. See Fig. 31-3.

As the piston continues to release, fluid forces the check valve off its seat and flows into the cylinder. When the piston releases to the point where the compensating port is uncovered, excess fluid will flow into the reservoir. Look at Fig. 31-4.

Most cars utilize disc brakes on the front, or on both front and rear. The hydraulic system action is essentially the same. Disc brakes will be covered later in this chapter.

ANTI-LOCK BRAKES

Many vehicles are now being equipped with anti-lock brake systems. These systems use electronic and hydraulic components to prevent wheel lockup during periods of hard braking. For more information on anti-lock brake systems, see Chapter 24.

SAFETY IN THE SHOP

Before beginning hands-on brake service, note this possible on-the-job hazard to your health.

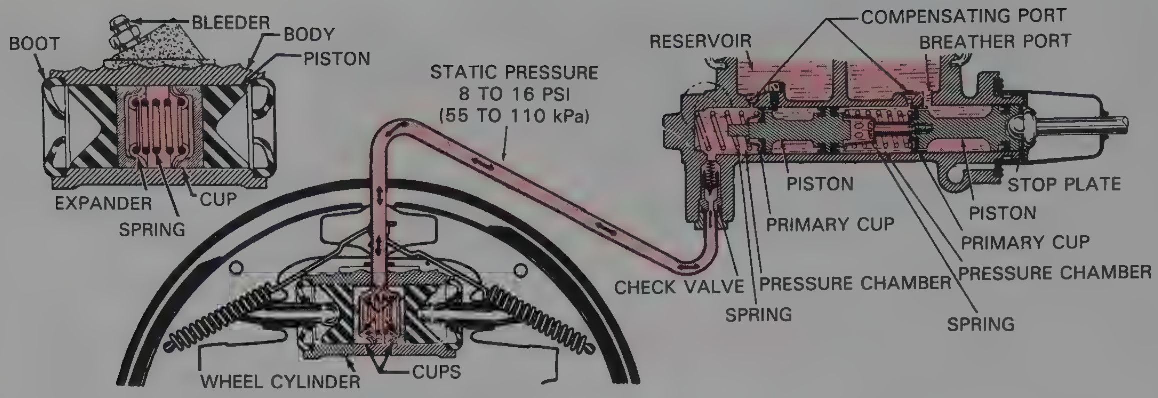

BLEEDER
BODY
BOOT
PISTON
EXPANDER
CUP
SPRING
STATIC PRESSURE
8 TO 16 PSI
(55 TO 110 kPa)
RESERVOIR
COMPENSATING PORT
BREATHER PORT
PISTON
STOP PLATE
PRIMARY CUP
PISTON
PRIMARY CUP
CHECK VALVE
PRESSURE CHAMBER
PRESSURE CHAMBER
SPRING
SPRING
WHEEL CYLINDER
CUPS

Fig. 31-1. Drum brake system with brakes released. (Buick)

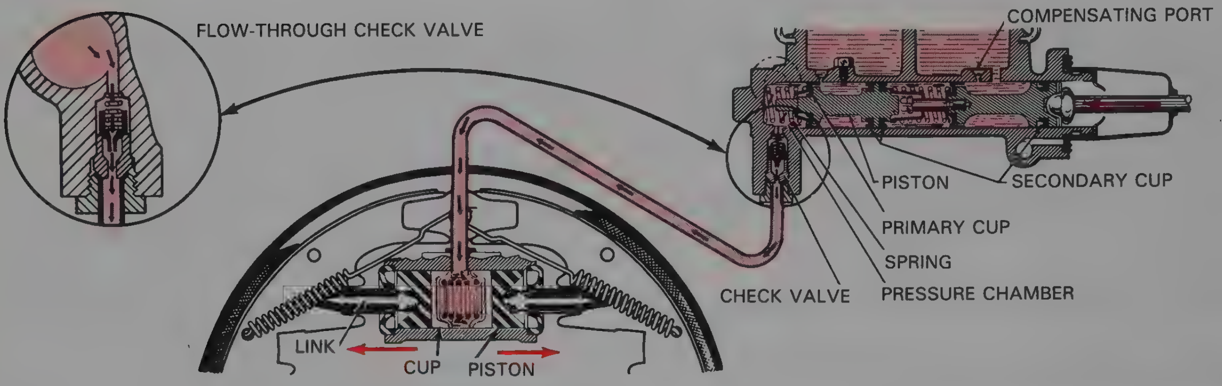

FLOW-THROUGH CHECK VALVE
COMPENSATING PORT
PISTON
SECONDARY CUP
PRIMARY CUP
SPRING
CHECK VALVE
PRESSURE CHAMBER
LINK
CUP
PISTON

Fig. 31-2. Drum brake system with brakes applied. (Buick)

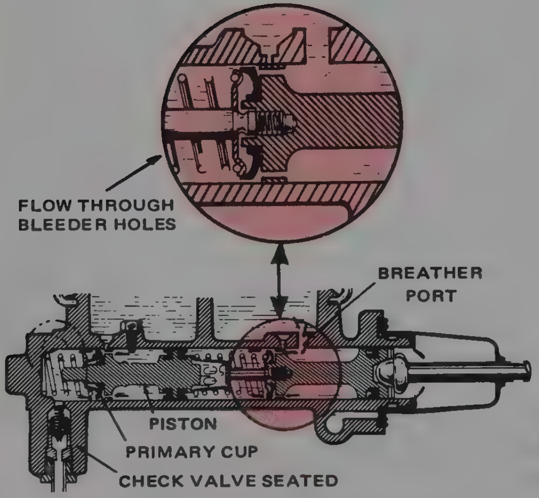

FLOW THROUGH
BLEEDER HOLES
BREATHER
PORT
PISTON
PRIMARY CUP
CHECK VALVE SEATED

Fig. 31-3. Master cylinder operation at start of fast release. (Buick)

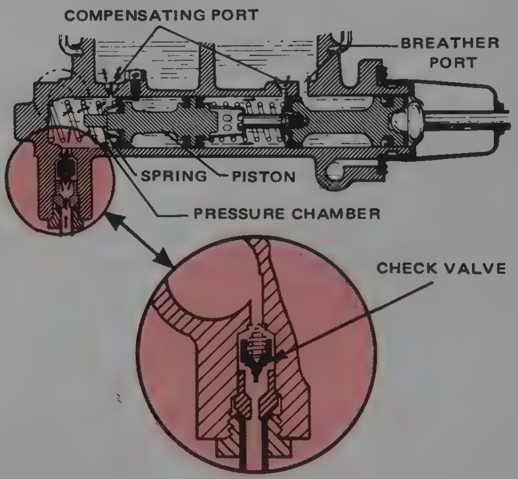

COMPENSATING PORT
BREATHER
PORT
SPRING
PISTON
PRESSURE CHAMBER
CHECK VALVE

Fig. 31-4. Master cylinder operation during finish of fast release. (Buick)

WARNING: BRAKE FRICTION MATERIALS CONTAIN ASBESTOS – A KNOWN CARCINOGEN (A SUBSTANCE THAT CAN CAUSE CANCER).

GRINDING LININGS, CLEANING BRAKE ASSEMBLIES, AND OTHER OPERATIONS CAN PRODUCE SMALL AIRBORNE PARTICLES OF ASBESTOS. THESE ARE EASILY INHALED BY THE MECHANIC. BREATHING THESE PARTICLES MAY CAUSE CANCER.

OBSERVE THE FOLLOWING RULES!

1. Never use compressed air to blow brake assemblies clean. Use a vacuum source or flush with water.
2. Equip brake shoe grinders with an efficient dust removal system. Turn on system whenever grinder is in operation.

3. When some exposure might be unavoidable, wear an approved filter mask.

BRAKE INSPECTION

Periodic brake inspections are a must for safe and efficient brake operation. The inspection should be thorough. It is best to develop a checklist so that no important area is overlooked.

BRAKE PEDAL AND MASTER CYLINDER: Check the brake pedal free play. Check the total pedal travel. There should be ample travel remaining when the brakes are fully applied. The pedal should be firm with no spongy feeling that could indicate air in the system. The pedal, when held firmly applied, must remain at one point and not slowly move towards the floor. Pedal action should be smooth and quiet.

Check the fluid level in the reservoir. If equipped with power brakes, exhaust the vacuum reservoir (engine off) by repeated brake applications. Hold the brake pedal down firmly while starting the engine. As soon as the engine starts, the brake pedal will move downward if the vacuum booster is functioning. Check for signs of leakage.

STOPLIGHT SWITCH: Check switch operation by inspecting brake lights while brake is being applied. Lights should come on quickly, even with very mild brake pressure.

WHEEL CYLINDERS AND BRAKE SHOE ASSEMBLIES: A periodic inspection generally involves pulling a wheel and drum. If any trouble is indicated (brake lining wear, fluid leakage, part scoring) all wheels should be removed.

Check the wheel cylinders for leakage by pulling back the lip of the dust boots. Any fluid, other than normal dampness, in the boot, indicates a leak. The shoe lining should have ample wear remaining and should be free of oil or grease. Inspect retracting springs, shoe hold-downs, automatic adjusting device, and shoe contact pads on the backing plate. Backing plate and shoe anchors must be tight.

BRAKE DRUMS: Check drums for out-of-round or tapered condition. Drum must be free of scoring, cracking, grease, and oil.

DISC BRAKES: Check brake pads for wear. Check rotor or disc for scoring, cracking, uneven wear, or warping. Caliper pistons should show no signs of leakage.

SEALS: Oil and grease seals must be in good condition with no visible signs of leakage.

PARKING BRAKE: The parking brake should hold the car securely. When the brake is firmly applied, there must still be ample pedal travel remaining. Check for missing cotter pins, frayed cables, rust, or other parts.

BRAKE LINES AND HOSES: Inspect all hoses for cracking, softening, or swelling. Check lines for leakage, damage from contact with moving parts, and vibration.

CHASSIS: The brake inspection must also include a check for loose wheel bearings, worn ball joints, worn steering parts, defective shock absorbers, broken struts, and worn springs. These parts can affect braking action.

ROAD TEST

Following the above checks, drive the car to test brake action. The car should stop quickly and smoothly. There must be no tendency to dive or to pull to one side or the other. Inspection points for a typical brake system are illustrated in Fig. 31-5.

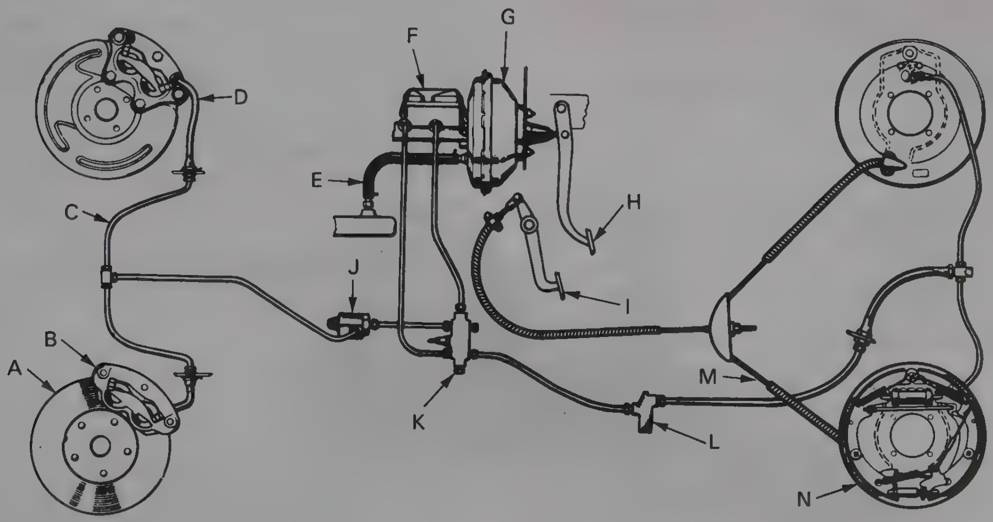


Fig. 31-5. Inspection points: A—Disc. B—Caliper. C—Line. D—Flex hose. E—Vacuum line. F—Master cylinder. G—Power booster. H—Brake pedal. I—Parking brake. J—Metering valve. K—Brake warning light. L—Proportioning valve. M—Parking brake cable system. N—Brake shoe assembly. (Bendix)

Full information on the inspection and servicing of all of the brake components will be given in this chapter.

DANGER! THE BRAKES, WHEN NEEDED, MUST WORK AND MUST WORK RIGHT.

MAKE EVERY INSPECTION THOROUGH. PERFORM ALL BRAKE WORK CAREFULLY AND TO THE HIGHEST STANDARDS. USE ONLY QUALITY PARTS. REFUSE TO DO ANY "HALF-WAY" JOBS.

REMEMBER THAT EVERYTIME THE PEDAL IS DEPRESSED, THE LIVES OF A NUMBER OF PEOPLE CAN DEPEND UPON YOUR SKILL, KNOWLEDGE, AND CARE. DO NOT LET THEM DOWN.

TYPICAL MASTER CYLINDER (SINGLE TYPE)

For many years, manufacturers used single piston master cylinders in most brake systems. Because they had only one operating piston, a faulty unit or a fluid leak could cause brake system failure. For this reason, single piston master cylinders are no longer used.

A cross-sectional view of a single piston master cylinder is shown in Fig. 31-6. Note that this type of master cylinder has only one brake fluid reservoir.

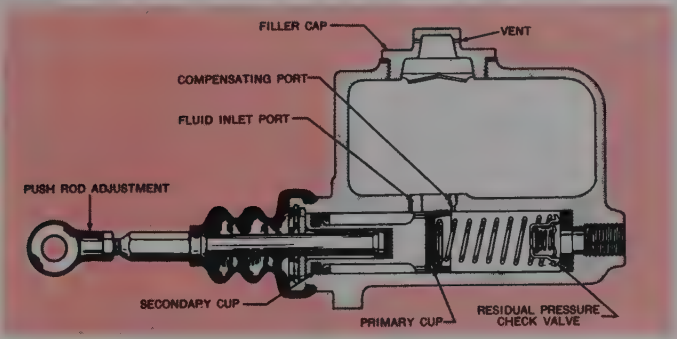

FILLER CAP
VENT
COMPENSATING PORT
FLUID INLET PORT
PUSH ROD ADJUSTMENT
SECONDARY CUP
PRIMARY CUP
RESIDUAL PRESSURE CHECK VALVE

Fig. 31-6. Typical single piston master cylinder.

TANDEM MASTER CYLINDER (DOUBLE PISTON, DUAL)

For years, the hydraulic brake system had one serious flaw in that a ruptured line or hose could cause instant and complete brake failure at all wheels. Even a slow fluid leak could finally reduce the supply of brake fluid to the point the brakes were no longer effective.

The double piston (also called dual piston or split system) master cylinder was developed so that the hydraulic systems for the front and rear wheels could be completely separated. With such a separation, a failure in the front system would not affect the rear and vice versa. The chance of both failing at once is unlikely.

One type of tandem (dual) or double piston master cylinder is shown in Fig. 31-7.

When the master cylinder push rod is forced inward, the primary piston moves toward the floating piston (also called secondary piston) until the compensating port is closed. Further movement of the primary piston is then transmitted to the floating piston. As the floating piston is forced forward by the hydraulic fluid separating it from the primary piston, it closes off the other compensating port. Further movement of the primary piston builds up pressure in both outlet systems (one to front brakes, other to rear).

Fig. 31-8 illustrates the action of the tandem cylinder in protecting against complete brake failure. In A, the master cylinder push rod is in the released position. In B, the push rod has forced the primary and floating pistons to build up pressure in both front and rear hydraulic systems. In C, the front brake line has ruptured, allowing the primary piston to move in until the floating piston struck the end of the cylinder. Pressure is still maintained to the rear wheels. In D, the rear wheel brake line has moved inward until it bumped the floating piston, thus maintaining pressure to the front wheel system.

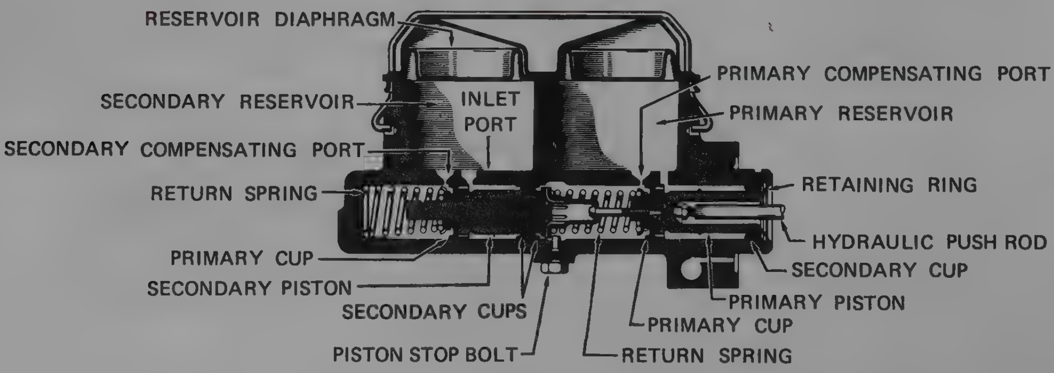

RESERVOIR DIAPHRAGM
SECONDARY RESERVOIR
INLET PORT
SECONDARY COMPENSATING PORT
RETURN SPRING
PRIMARY CUP
SECONDARY PISTON
SECONDARY CUPS
PISTON STOP BOLT
PRIMARY COMPENSATING PORT
PRIMARY RESERVOIR
RETAINING RING
HYDRAULIC PUSH ROD
SECONDARY CUP
PRIMARY PISTON
PRIMARY CUP
RETURN SPRING

Fig. 31-7. Typical tandem (dual) master cylinder. (Bendix)

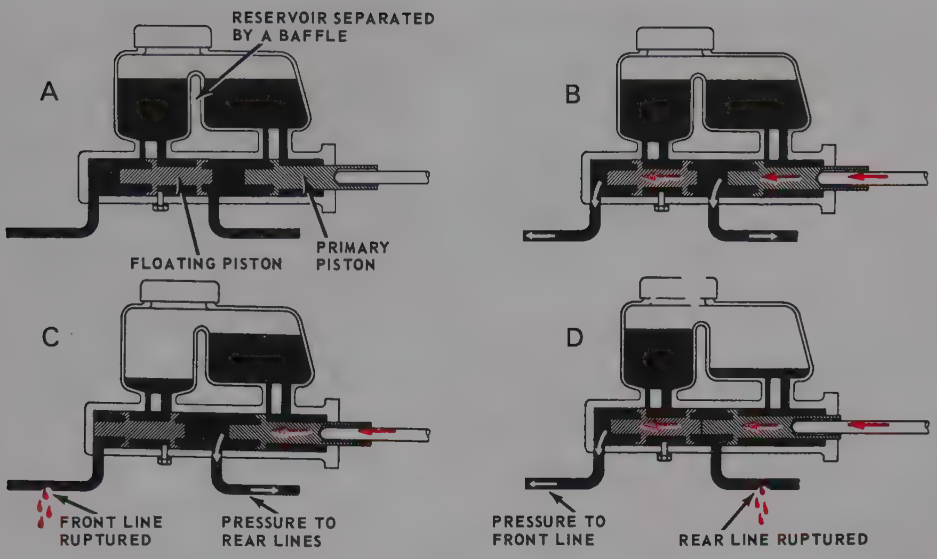


Fig. 31-8. Action of tandem master cylinder in event of either front or rear brake system failure. (Mercedes-Benz)

Failure of either the front or rear system will be evidenced by a sudden increase in the brake pedal travel required to apply the brakes. A pressure differential safety switch is used to activate a warning light.

Fig. 31-15 also illustrates a dual master cylinder. Note the location of the residual check valves in this unit.

Some tandem master cylinders have completely separate reservoirs, Fig. 31-7. Others merely use a baffle to form two reservoirs. Look at Fig. 31-8.

COMPACT MASTER CYLINDER

The compact master cylinder is a composite design (plastic reservoir and aluminum body) master cylinder that is used in diagonally split brake systems, Fig. 31-9.

Compact master cylinders incorporate the functions of a standard dual master cylinder, a fluid level sensor, and integral proportioners. The proportioners are used to improve front to rear balance during heavy brake applications.

QUICK TAKE-UP MASTER CYLINDER — CONSTRUCTION

The quick take-up master cylinder is designed to be used with low drag disc brake calipers. A proportioning valve and warning light switch are housed in an integral bore located on the bottom of the cylinder.

The cylinder housing is usually made of aluminum. The fluid reservoir is constructed of nylon. A quick take-up master cylinder is shown in Fig. 31-10.

There are four separate outlet ports on the cylinder housing. Each feeds an individual brake assembly. See Fig. 31-11.

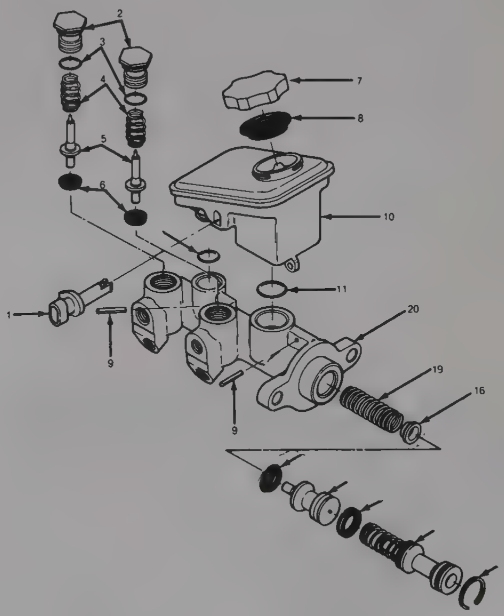


Fig. 31-9. Exploded view of a compact master cylinder assembly. Note plastic reservoir assembly (10) and aluminum cylinder body (20). (Pontiac)

QUICK TAKE-UP MASTER CYLINDER OPERATION — APPLICATION

The quick take-up feature is designed to supply a large volume of low pressure fluid to the brakes during the start of application. This low pressure fluid rapidly supplies the increased fluid displacement needs caused by the no-drag caliper pistons.

During the start of brake application, more fluid is displaced in the low pressure primary chamber than the high pressure chamber. This displacement is created

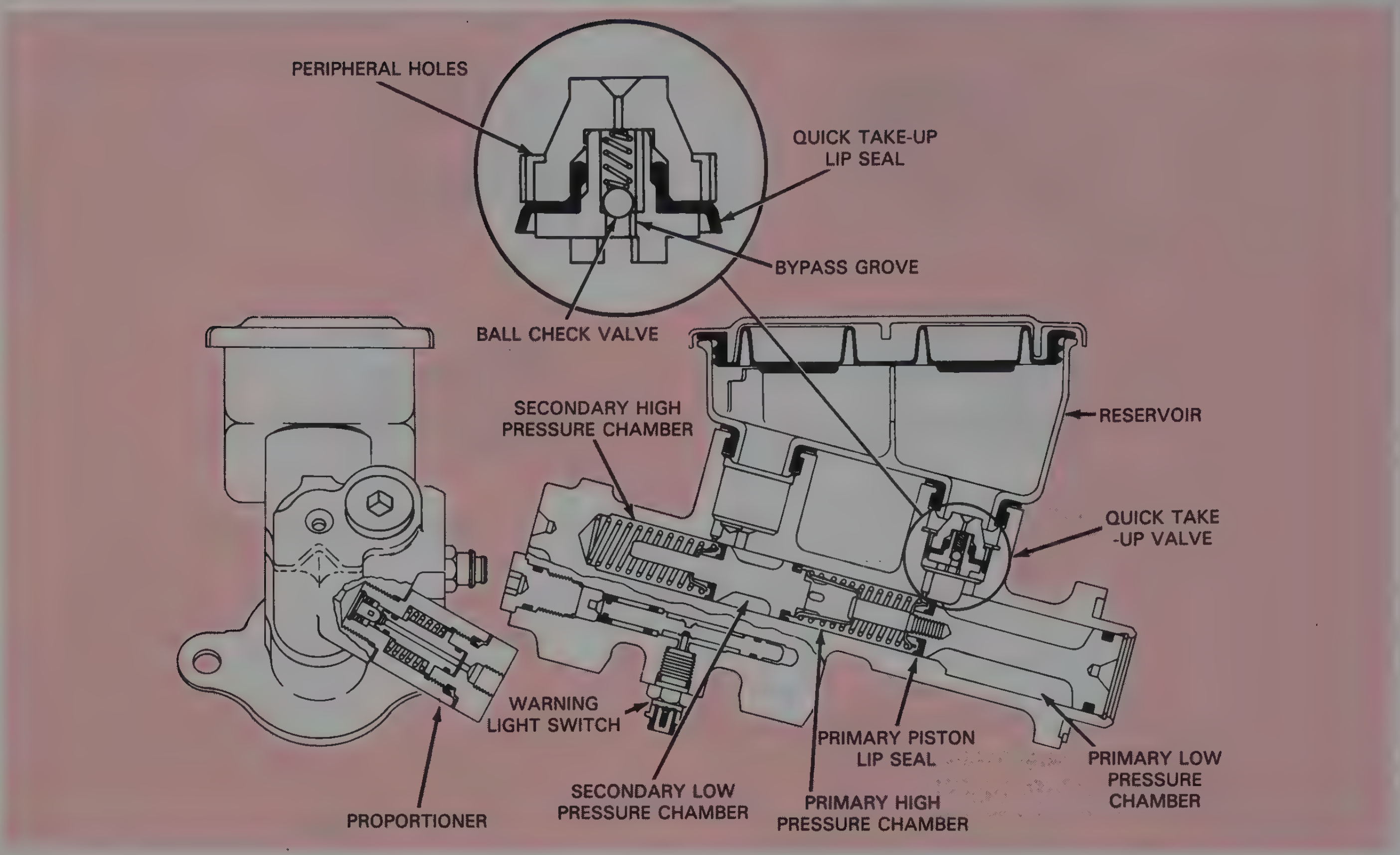

PERIPHERAL HOLES
QUICK TAKE-UP LIP SEAL
BYPASS GROVE
BALL CHECK VALVE
SECONDARY HIGH PRESSURE CHAMBER
RESERVOIR
QUICK TAKE -UP VALVE
WARNING LIGHT SWITCH
PRIMARY PISTON LIP SEAL
PRIMARY LOW PRESSURE CHAMBER
SECONDARY LOW PRESSURE CHAMBER
PRIMARY HIGH PRESSURE CHAMBER
PROPORTIONER

Fig. 31-10. Cutaway view of a quick take-up master cylinder. Note that this unit also has a warning light switch and proportioner attached to cylinder body. (Delco)

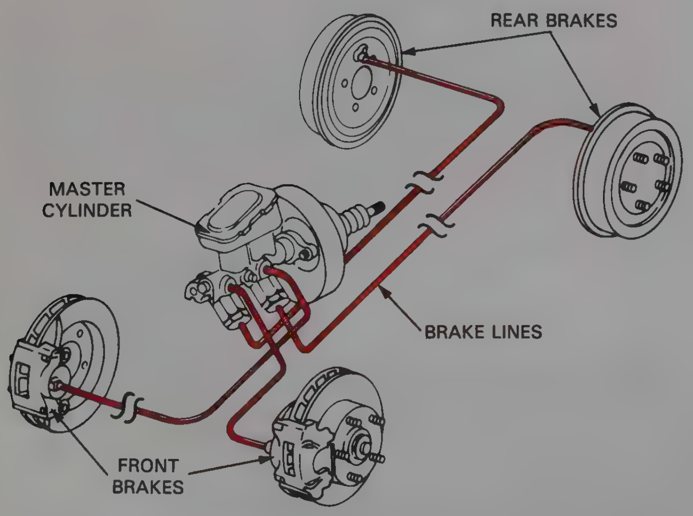

REAR BRAKES
MASTER CYLINDER
BRAKE LINES
FRONT BRAKES

Fig. 31-11. Schematic of a diagonal split braking system. Each brake line has its own attachment point on master cylinder. (Bendix)

by the larger diameter low pressure chamber, over that of the high pressure one.

As continued application occurs, brake fluid is then forced around the outer edge of the primary piston lip seal. From there it goes into the high pressure chamber, and on to the braking units at the wheels. Look at Fig. 31-12, A.

To create equal pressure and displacement in both systems, the primary piston travels a lesser amount than the secondary piston.

Now that caliper piston and wheel cylinder piston travel is taken up, a higher pressure begins to build in the system. At a preset pressure (generally 70 to 100 psi or 482.6 to 689.5 kPa) the quick take-up valve "ball check" opens. This allows excess fluid in the larger primary chamber to flow into the reservoir. See Fig. 31-12, B.

Once the primary piston lip seal has passed the quick take-up valve port, high pressure is built up ahead of each piston. The master cylinder functions like a conventional unit.

QUICK TAKE-UP MASTER CYLINDER OPERATION — RELEASING

When the brakes are released, the master cylinder piston springs return the pistons faster than the returning fluid can travel. A vacuum is then generated in both the high and low pressure chambers. If the vacuum were not relieved, fluid would pass around the piston

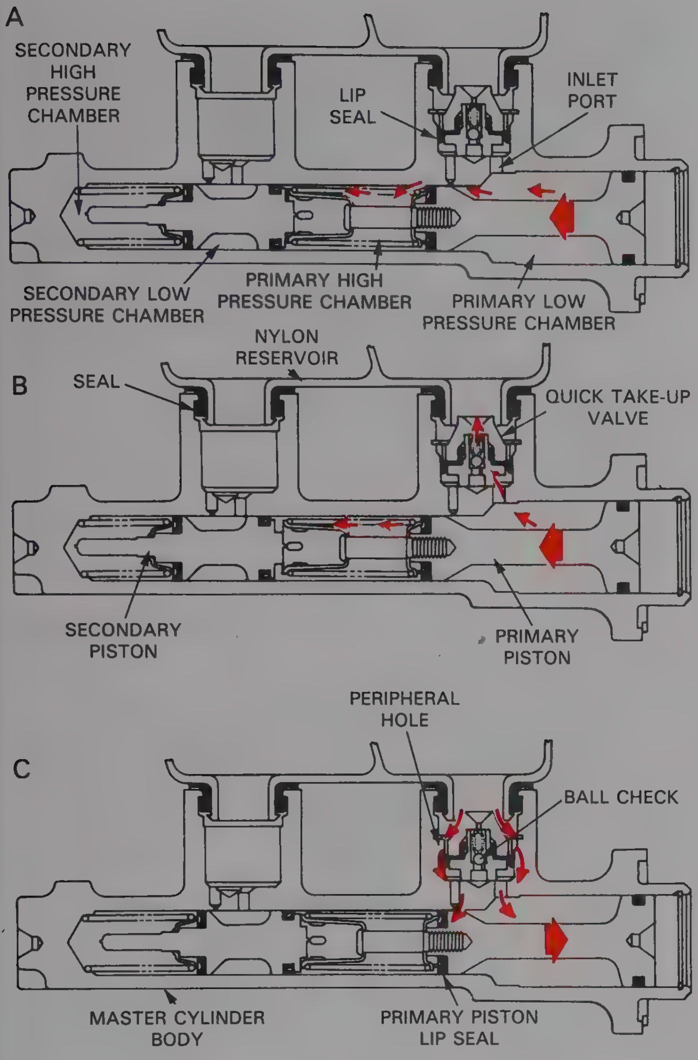


Fig. 31-12. Operation sequences of a quick take-up master cylinder. A—Start of quick take-up application. Note fluid flowing around primary piston cup. B—Primary piston and secondary piston now have equal pressure. Cylinder now operates as a conventional unit. Note fluid flow through quick take-up valve into reservoir. C—Releasing. (Delco)

seal cup lips in an effort to eliminate the vacuum. Look at Fig. 31-12, C.

To stop this vacuum from forming, the primary chamber vacuum will be compensated by the bypass groove in the quick take-up valve. The primary piston is compensated by fluid traveling through small diameter holes in the quick take-up valve, as it flows from the reservoir. The secondary piston chamber vacuum is relieved by fluid traveling from the reservoir through the compensating port and bypass hole.

QUICK TAKE-UP MASTER CYLINDER — SERVICE

This master cylinder is serviced in about the same way as the conventional dual unit, with several exceptions. DO NOT try to clean the inside bores of this aluminum cylinder with abrasives of any kind. Cleaning cylinder bore with sandpaper or a hone will remove the protective, anodized surface which helps prevent corrosion, pitting, and scratching.

If corrosion, pits, or other surface imperfections are visible, replace master cylinder. DO NOT use any master cylinder repair parts such as cast iron pistons or springs unless they are specifically for aluminum cylinders. DO NOT use excessive force (by hand or with tools) to remove the nylon reservoir. When replacing the reservoir, be sure it is not installed backwards and that new O-ring seals are used if recommended.

Be careful not to strip threads when installing lines or mounting bolts to the aluminum cylinder. Follow maker's recommended service cautions and procedures.

CHECKING MASTER CYLINDER

The master cylinder fluid level can be checked in severals ways. After thoroughly cleaning cover(s) and surrounding area, remove to expose fluid. Fluid level should be around 1/4 in. (6.35 mm) from the top of the reservoirs, G, Fig. 31-13. Fluid must be clean and free of discoloration. Make sure that the cover vent, C, a tiny hole, is open to prevent pressure buildup in reservoir. Check condition and placement of reservoir seal diaphragm, F. Bail wire, D, must snap on tightly.

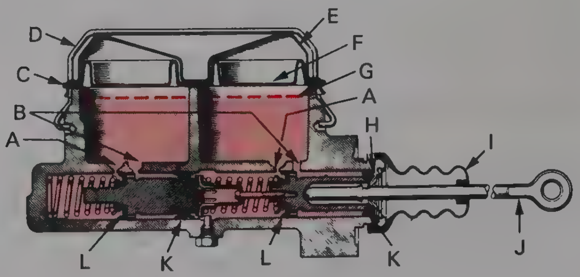


Fig. 31-13. Master cylinder check points. A—Compensating ports. B—Inlet ports. C—Vent. D—Bail. E—Reservoir cover. F—Diaphragm reservoir seal. G—Fluid level. H—Push rod retainer. I—Dust boot. J—Push rod. K—Secondary cups. L—Primary cups. (Bendix)

Inspect beneath dust boot, I, for evidence of fluid leakage past the secondary cup, K. Check primary cups, L, by applying the brakes firmly. Hold pressure. The pedal should not move inward. If it does, it indicates that one or both primary cups could be allowing fluid to escape. A leak elsewhere in system will also cause pedal to fall away.

The compensating ports, A, must be open when the pedal is released. If it is closed by dirt, corrosion, swollen primary cup, or improper linkage adjustment, it can cause a pressure buildup in the lines that will keep the brakes applied.

Nylon reservoirs are usually equipped with moulded-in (thin area) windows which are used to view the fluid level. See Fig. 31-14.

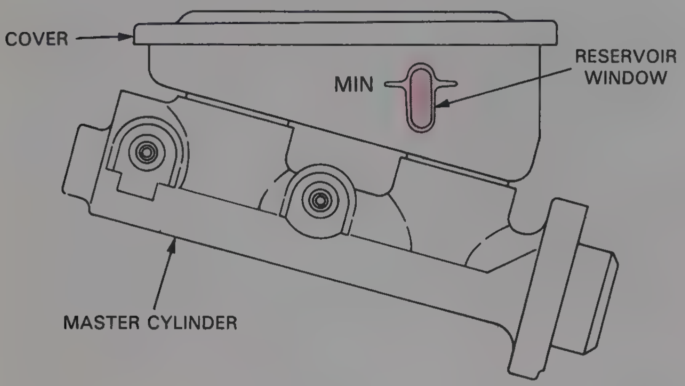

COVER
MIN
RESERVOIR WINDOW
MASTER CYLINDER

Fig. 31-14. Master cylinder reservoir window. Cover does not have to be removed to check fluid level. (Pontiac)

Residual check valves, where used (drum brakes only), must function properly to maintain a static pressure in the lines. A faulty check valve can cause excessive pedal travel before the brakes apply. Worn linings or improperly centered shoes can also cause excessive pedal travel.

The check valve can be tested by applying and releasing the brakes, then cracking open a wheel cylinder bleed screw. If residual pressure is present, a brief spurt of fluid will occur.

MASTER CYLINDER REPAIR

Remove the master cylinder. Cap the brake lines to prevent entry of foreign material. Scrape off exterior dirt. Wash off in denatured alcohol. Remove push rod where used (some require removal of stop plate or retainer, first). WATCH OUT! SOME STOP PLATE RETAINING RINGS CAN FLY OUT WITH GREAT FORCE! Hold piston in until snap ring is removed, Fig. 31-15. Withdraw pistons, springs, and other parts.

If residual check valves are used, remove the check valves by pulling the tube seats. This is done by threading a screw into the seat and prying up on the screw, Fig. 31-16.

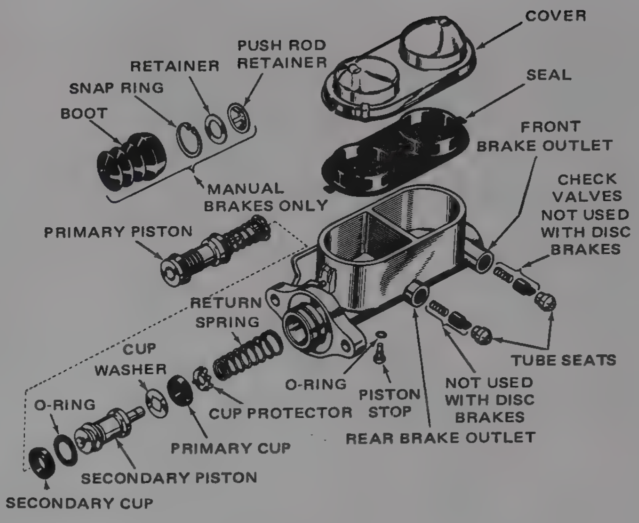

COVER
PUSH ROD RETAINER
RETAINER
SNAP RING
BOOT
SEAL
FRONT BRAKE OUTLET
MANUAL BRAKES ONLY
CHECK VALVES NOT USED WITH DISC BRAKES
PRIMARY PISTON
RETURN SPRING
CUP WASHER
TUBE SEATS
O-RING
O-RING
PISTON STOP
NOT USED WITH DISC BRAKES
CUP PROTECTOR
PRIMARY CUP
REAR BRAKE OUTLET
SECONDARY PISTON
SECONDARY CUP

Fig. 31-15. Exploded view of a master cylinder. (American Motors)

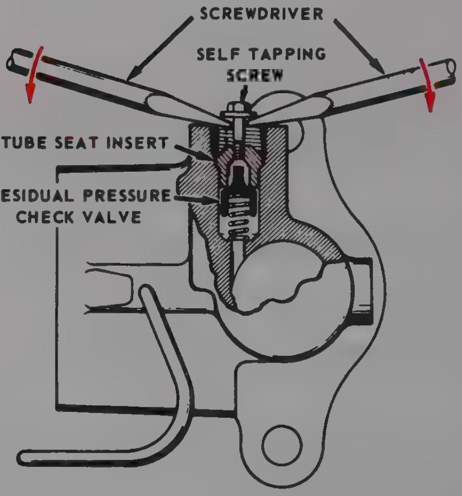

SCREWDRIVER
SELF TAPPING SCREW
TUBE SEAT INSERT
RESIDUAL PRESSURE CHECK VALVE

Fig. 31-16. Pulling tube seat insert to free check valve for removal.

USE SPECIAL SOLUTIONS FOR CLEANING

CLEAN ALL PARTS IN CLEAN, DENATURED (ISOPROPYL) ALCOHOL, RECOMMENDED BRAKE CLEANING SOLUTION, OR BRAKE FLUID. NEVER, UNDER ANY CIRCUMSTANCES, MUST THE BRAKE SYSTEM RUBBER PARTS BE PLACED IN CONTACT WITH GASOLINE, KEROSENE, DIESEL OIL, OR ANY TYPE OF CLEANER OTHER THAN AN APPROVED TYPE. NEVER TOUCH RUBBER PARTS WITH OILY OR GASOLINE SOAKED FINGERS. WASH HANDS WITH SOAP AND WATER BEFORE HANDLING PARTS.

If exceptionally dirty, it is permissible to wash disassembled cylinder body, head nut, push rod, and reservoir cap in fresh cleaning solvent PROVIDED THESE PARTS ARE BLOWN DRY, RINSED IN ALCOHOL, BLOWN DRY, RINSED AGAIN IN FRESH ALCOHOL, AND ONCE AGAIN BLOWN DRY.

When all parts are clean, inspect cylinder surface. Hold it up to a good light. Scoring, pitting or heavy corrosion will require discarding entire master cylinder.

Minor (very light) scratches and corrosion can be removed with crocus cloth. Do not use emery cloth or sandpaper.

The cylinder, in some cases, can be honed to remove minor scratches. The hone stones must be true, clean, and extremely smooth. Hone as little as possible. Use brake fluid as a hone lubricant. Place crocus cloth over the hone stones for a final smoothing.

Some manufacturers diamond bore the master cylinder to a very smooth finish and then roll the surface to produce a glassy finish. Honing during service will destroy this finish and in such cases is not recommended. DO NOT attempt to remove scratches, pits, or corrosion from ALUMINUM master cylinder bores. This removes the protective anodized surface. If any scratches or pits show or if aluminum can be seen through the anodizing, the cylinder MUST be replaced.

When the cylinder has been cleaned, scrub the bore with a clean, lint free cloth dipped in alcohol. Flush with alcohol, blow dry, flush, and blow dry again. Compressed air must be oil free.

CHECK PISTON-TO-CYLINDER CLEARANCE

Use a No-Go gauge to check the cylinder diameter. If such a gauge is not available, place the piston in the bore. Use a clean, narrow feeler gauge to check the clearance between piston and cylinder. If the clearance exceeds .005 in. (0.127 mm), the cylinder must be scrapped.

PORTS MUST BE OPEN AND FREE OF BURRS

Check the compensating and inlet or breather ports. They must be clean and open. The compensating port may be cleaned by passing a thin (.020 in. or 0.508 mm), smooth, copper wire through the opening. Do not pass square or rough tipped steel wires through the port.

If a burr is present at the port, remove it with a deburring tool. The slightest burr will cut the primary cup and cause leakage. Remove all burrs.

Give all parts a final rinse with clean alcohol and blow dry.

LUBRICATE WITH BRAKE FLUID

Coat the cylinder wall with brake fluid. Dip the piston and rubber cups in clean brake fluid. Assemble in the reverse order of disassembly.

Cylinder, cups, and pistons must be coated with brake fluid before assembly. Parts assembled dry can cause sticking and scoring. Use a repair kit if cylinder is in excellent condition. Never install old parts. Make certain piston stop plate lock ring is properly engaged.

BLEED MASTER CYLINDER BEFORE INSTALLING

Attach bleeder tubes, Fig. 31-17. Fill reservoir partly full (above end of bleeder tubes) of recommended brake fluid. Force pistons in and out several times until all air is dispelled from the cylinder. Maintain reservoir level while bleeding. Remove bleed tubes. Install cover to prevent fluid contamination.

Plugs or a special bleeding syringe can be used in place of the bleed tubes. Follow manufacturer's recommendations. See Figs. 31-18 and 31-19.

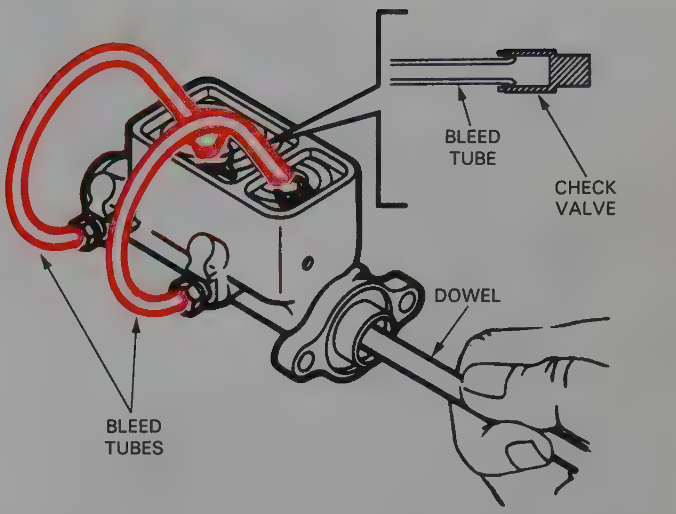


Fig. 31-17. Bench bleeding master cylinder before installing. Note bleeder tubes. Operate pistons until all air is expelled. (American Motors)

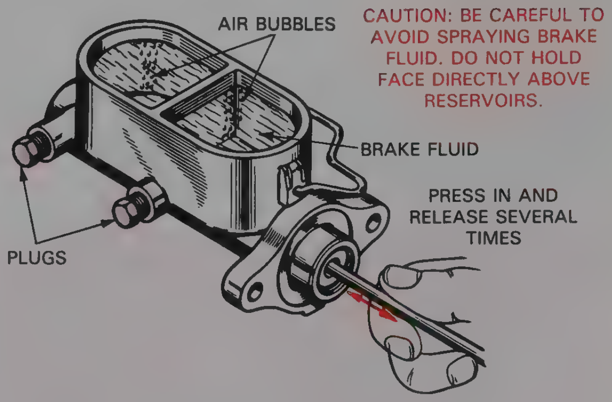

AIR BUBBLES
CAUTION: BE CAREFUL TO AVOID SPRAYING BRAKE FLUID. DO NOT HOLD FACE DIRECTLY ABOVE RESERVOIRS.
BRAKE FLUID
PRESS IN AND RELEASE SEVERAL TIMES
PLUGS

Fig. 31-18. Bleeding master cylinder with aid of plugs. Force pistons in and out until air bubbles stop. Install cylinder. (Bendix)

Install the cylinder and connect the lines. At this time, it is good practice to crack each master cylinder line connection open a small amount. Wrap a rag around it. Depress the brake pedal gently to force remaining air out of the master cylinder. Tighten connection before releasing. Adjust brake pedal. Bleed the brakes (discussed later in this chapter). Fill master cylinder to proper level and install cap and seal. CAUTION! Avoid spraying brake fluid. Wear safety goggles.

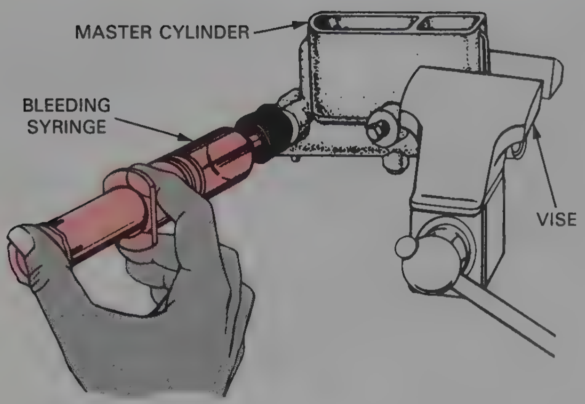

MASTER CYLINDER
BLEEDING SYRINGE
VISE

Fig. 31-19. Master cylinder being bled with special syringe. Plug outlet holes. Fill cylinder with fluid (about 1/2 full). Remove a plug. Depress syringe plunger fully. Place firmly against outlet. Pull plunger out until syringe is half full. Remove syringe. Point straight up. Expel air until fluid squirts out. Put syringe (with fluid) on same outlet. Depress plunger. When air bubbles in reservoir stop, remove syringe and plug outlet. Repeat on other outlets. Plug outlets firmly. (EIS)

BRAKE FLUID WILL RUIN PAINT

Do not spill brake fluid on the car's paint. If fluid gets on a painted surface, wipe off and wash with mild soap and water at once. Remember most brake fluids (other than SILICONE) can ruin a paint job.

Fig. 31-20 illustrates the many parts of a typical master cylinder. ALL parts should be carefully inspected during service.

REMEMBER: DO NOT TRY TO SALVAGE A MASTER CYLINDER UNLESS THE CYLINDER IS IN EXCELLENT CONDITION. TRYING TO SAVE A FEW PENNIES CAN COST DEARLY.

ADJUSTING BRAKE PEDAL HEIGHT

If pedal has an adjustable stop, measure distance from toeboard to bottom of pedal. Check against specifications and adjust if needed, Fig. 31-21.

ADJUSTING BRAKE PEDAL FREE TRAVEL

Brake pedal free travel means the distance the pedal moves before the push rod engages the cylinder piston. Free travel is needed to insure that the piston will not be held in the forward position far enough to keep the compensating port closed.

Free travel is automatically set on some cylinders, when the brake pedal height is correctly adjusted by lengthening or shortening the push rod clevis. Such is the case of the type shown in Fig. 31-21.

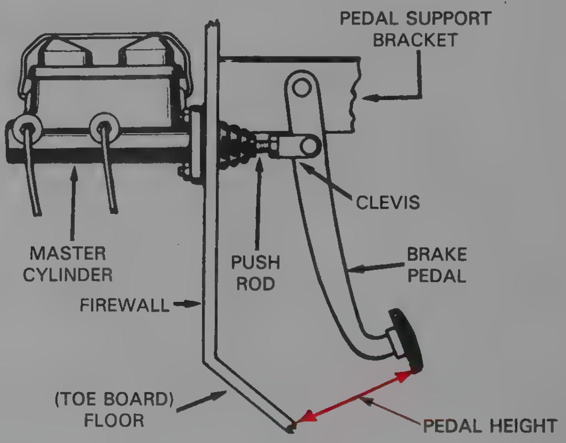

PEDAL SUPPORT BRACKET
CLEVIS
MASTER CYLINDER
PUSH ROD
BRAKE PEDAL
FIREWALL
(TOE BOARD) FLOOR
PEDAL HEIGHT

Fig. 31-21. Brake pedal height should be as specified.

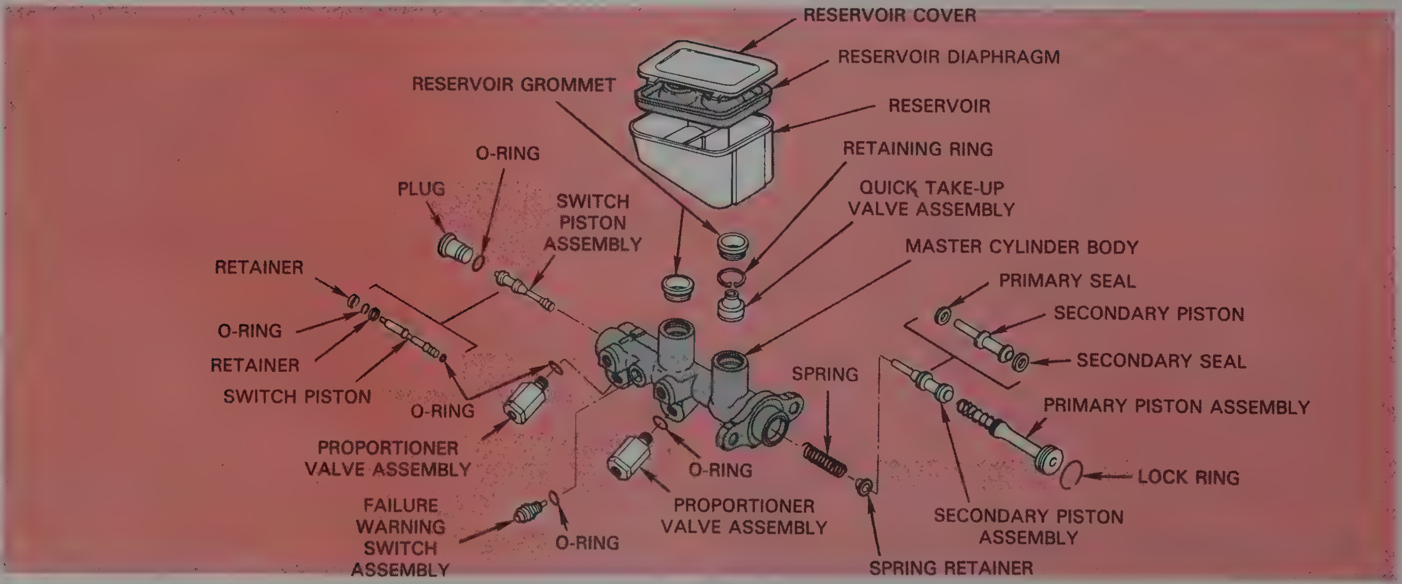

RESERVOIR COVER
RESERVOIR DIAPHRAGM
RESERVOIR GROMMET
RESERVOIR
O-RING
RETAINING RING
PLUG
SWITCH PISTON ASSEMBLY
QUICK TAKE-UP VALVE ASSEMBLY
MASTER CYLINDER BODY
RETAINER
PRIMARY SEAL
O-RING
SECONDARY PISTON
RETAINER
SPRING
SECONDARY SEAL
SWITCH PISTON
O-RING
PRIMARY PISTON ASSEMBLY
PROPORTIONER VALVE ASSEMBLY
O-RING
LOCK RING
FAILURE WARNING SWITCH ASSEMBLY
PROPORTIONER VALVE ASSEMBLY
SECONDARY PISTON ASSEMBLY
O-RING
SPRING RETAINER

Fig. 31-20. Exploded view of one type of master cylinder. Carefully inspect ALL parts during service. Follow manufacturer's overhaul procedures carefully. (Bendix)

Other types utilize a separate pedal stop. The push rod is adjusted until the correct free travel exists. Fig. 31-22 illustrates pedal free travel.

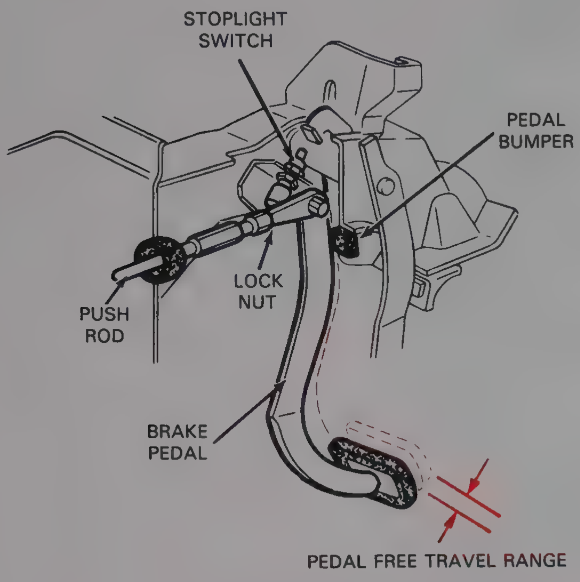

STOPLIGHT SWITCH
PEDAL BUMPER
LOCK NUT
PUSH ROD
BRAKE PEDAL
PEDAL FREE TRAVEL RANGE

Fig. 31-22. Brake pedal free travel.

If the master cylinder is mounted to a power booster, check the distance from push rod to face of booster. Use a special gauge and adjust (where possible) as needed before mounting cylinder, Figs. 31-23 and 31-24.

Proper free travel for manual (nonpower) brakes is around 1/4 to 1/2 in. (6.35 to 12.70 mm). For power assisted brakes, free travel ranges from 1/8 to 3/8 in. (3.18 to 9.53 mm).

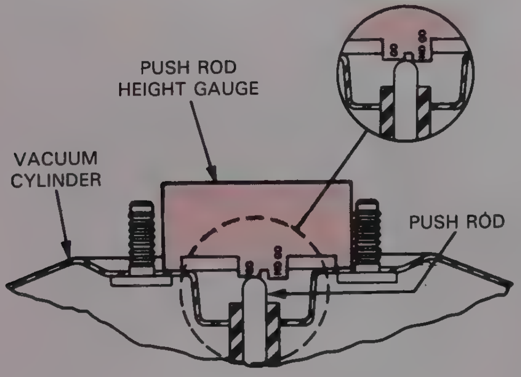

PUSH ROD HEIGHT GAUGE
VACUUM CYLINDER
PUSH ROD

Fig. 31-23. Checking distance master cylinder push rod protrudes from vacuum booster unit. (Pontiac)

POWER BRAKES

A power booster is used with a regular master cylinder to reduce required pedal travel and to produce needed hydraulic pressures with a relatively small amount of foot pressure.

The unit commonly utilizes engine vacuum and atmospheric pressure acting on a diaphragm to apply pressure directly to the master cylinder pistons, Fig. 31-25. A typical diaphragm power booster is pictured in Fig. 31-26.

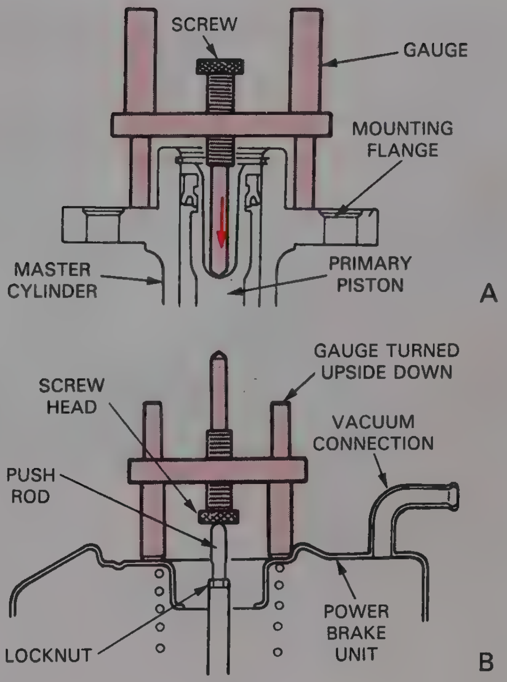

SCREW
GAUGE
MOUNTING FLANGE
MASTER CYLINDER
PRIMARY PISTON
A
SCREW HEAD
GAUGE TURNED UPSIDE DOWN
VACUUM CONNECTION
PUSH ROD
LOCKNUT
POWER BRAKE UNIT
B

Fig. 31-24. Special adjustable gauge being used to measure and set push rod length. A—Gauge set on master cylinder mounting flange. Screw is turned in until it just touches primary piston. B—Gauge is turned upside down and placed on power brake unit. Loosen locknut and turn push rod until it just touches screw head. Tighten locknut. Proper push rod clearance is now set. (Mazda)

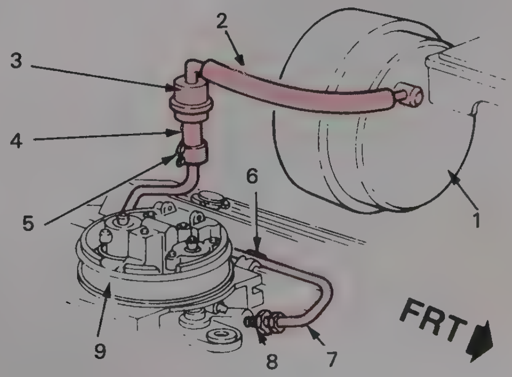

1
2
3
4
5
6
7
8
9
FRT

Fig. 31-25. Typical power booster vacuum hose layout. Note the filter check valve, which prevents vacuum from escaping the reservoir and stops harmful engine fumes. 1—Booster. 2—Vacuum hose. 3—Filter-check valve. 4—Hose. 5—Clamp. 6—Retaining clip. 7—Pipe. 8—Intake manifold connection. 9—Throttle body. (Pontiac)

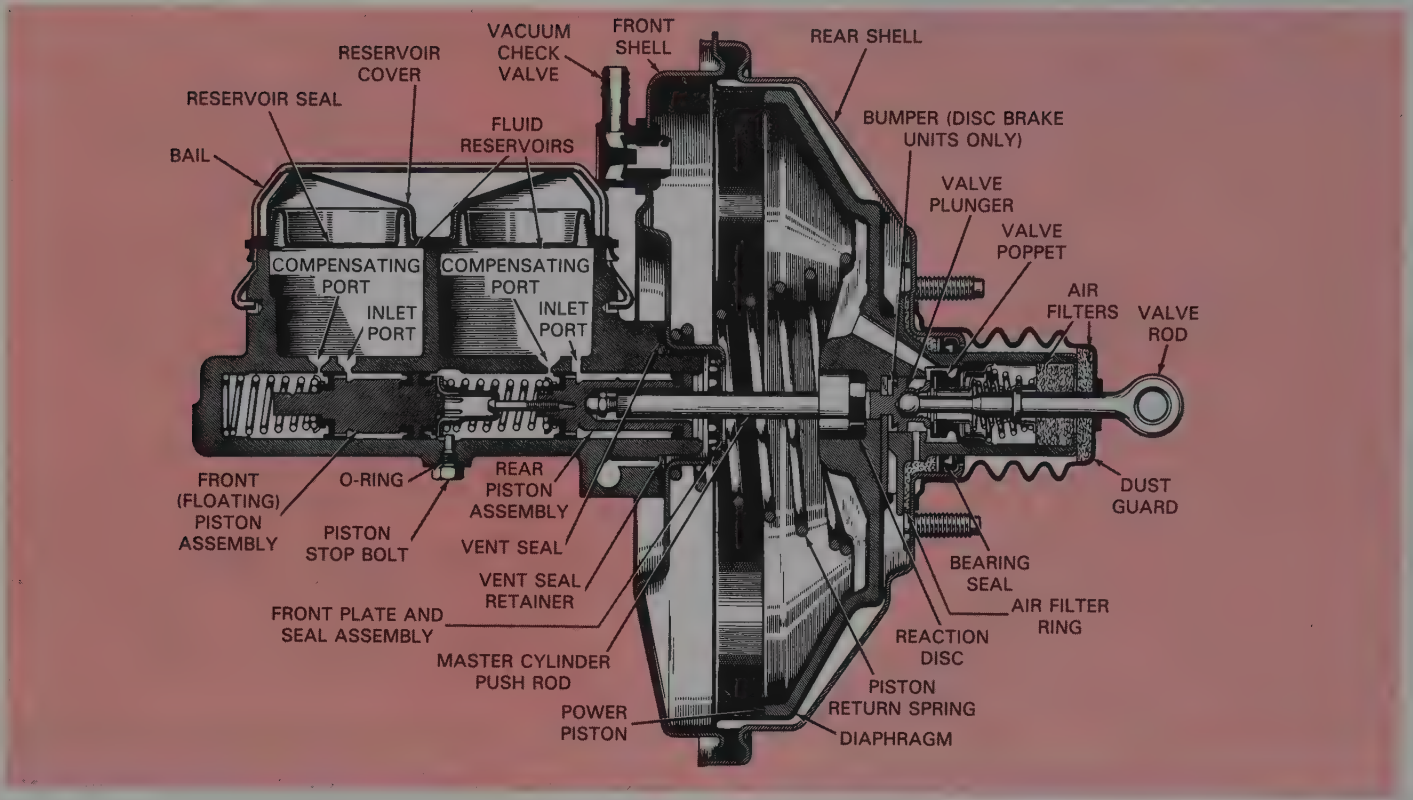

VACUUM CHECK VALVE
FRONT SHELL
REAR SHELL
RESERVOIR COVER
RESERVOIR SEAL
BAIL
FLUID RESERVOIRS
BUMPER (DISC BRAKE UNITS ONLY)
VALVE PLUNGER
VALVE POPPET
COMPENSATING PORT
INLET PORT
COMPENSATING PORT
INLET PORT
AIR FILTERS
VALVE ROD
DUST GUARD
FRONT (FLOATING) PISTON ASSEMBLY
O-RING
REAR PISTON ASSEMBLY
PISTON STOP BOLT
VENT SEAL
VENT SEAL RETAINER
FRONT PLATE AND SEAL ASSEMBLY
MASTER CYLINDER PUSH ROD
POWER PISTON
BEARING SEAL
AIR FILTER RING
REACTION DISC
PISTON RETURN SPRING
DIAPHRAGM

Fig. 31-26. Typical power brake setup. Note how a diaphragm is used to seal between the housing and power piston. (Pontiac)

A booster is shown in the released position in Fig. 31-27. Note that engine vacuum exists on both sides of the diaphragm.

When brake pedal forces push rod inward, vacuum port is closed and atmospheric port is opened, admitting atmospheric pressure to one side of diaphragm. This moves diaphragm assembly, causing master cylinder push rod to actuate master cylinder pistons and build up hydraulic pressure in system, Fig. 31-28. Other

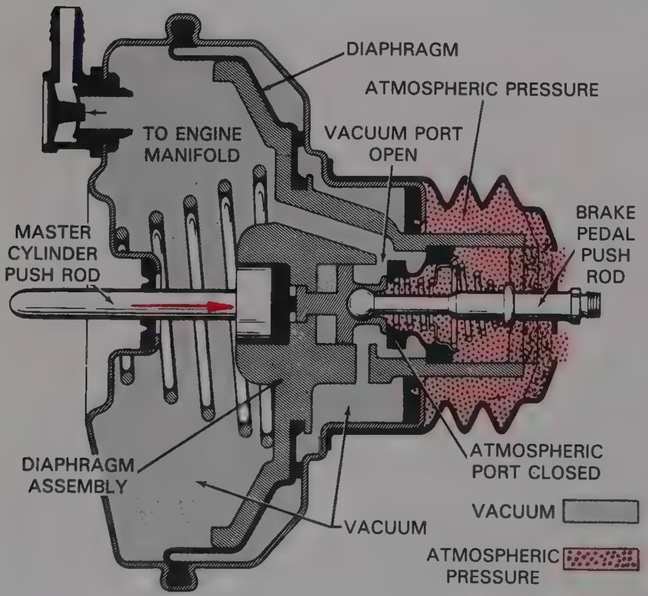

DIAPHRAGM
ATMOSPHERIC PRESSURE
TO ENGINE MANIFOLD
VACUUM PORT OPEN
BRAKE PEDAL PUSH ROD
MASTER CYLINDER PUSH ROD
DIAPHRAGM ASSEMBLY
ATMOSPHERIC PORT CLOSED
VACUUM
VACUUM
ATMOSPHERIC PRESSURE

Fig. 31-27. Power booster in released position. (Chevrolet)

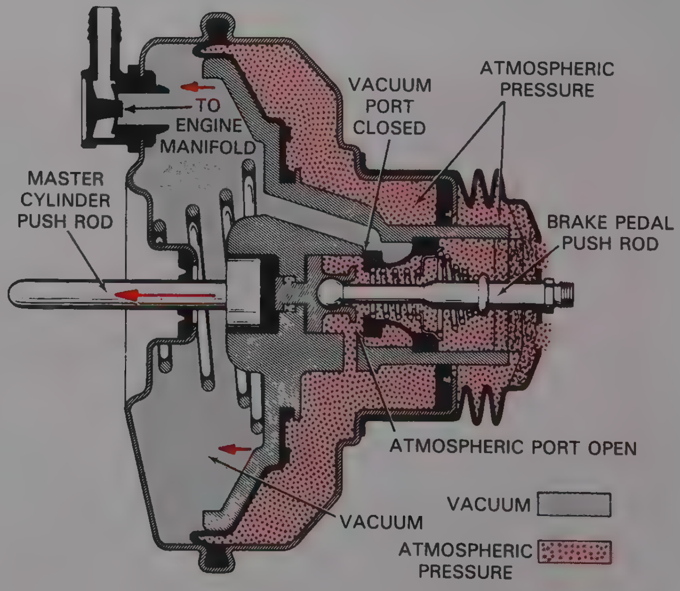

ATMOSPHERIC PRESSURE
TO ENGINE MANIFOLD
VACUUM PORT CLOSED
MASTER CYLINDER PUSH ROD
BRAKE PEDAL PUSH ROD
ATMOSPHERIC PORT OPEN
VACUUM
VACUUM
ATMOSPHERIC PRESSURE

Fig. 31-28. Power booster in applied position. Note how atmospheric pressure acting on diaphragm forces the push rod toward master cylinder. (Chevrolet)

boosters, some containing two diaphragms for increased pressure, are also used.

CHECKING POWER BRAKE OPERATION

With the engine stopped, exhaust the vacuum in the vacuum tank by making several brake applications.

While holding firm foot pressure on the brake pedal, start the engine. If the unit is functioning properly, the pedal will move downward when the engine starts. If it does not, check the amount of vacuum at the booster vacuum inlet. It should be the same as existing engine vacuum.

POWER BOOSTER MAINTENANCE

Periodic inspection of the vacuum lines should be performed. Replace any cracked, soft, or otherwise defective lines.

The engine should be in sound mechanical condition so that a proper vacuum is created. Check for vacuum leaks. When the engine is shut off, the vacuum should remain in the lines. Loss of vacuum indicates a leak.

Clean or replace the atmospheric air filter. Some booster units require periodic lubrication with booster oil. Do not lube boosters unless specified and then only with the correct oil.

If the power unit needs repair, exhaust the static vacuum in the lines by pressing on the brake pedal several times.

On some units the booster can be removed without disturbing the master cylinder. On others, the entire assembly must be removed.

Disassemble the vacuum booster. Clean all rubber parts in alcohol. Check parts for wear and replace as needed. The power piston (sliding type) cylinder wall must be free of rust and dents.

Assemble unit, using care to place all parts in the correct position. Use special lubricant where required. Use new gaskets. Use sealer where needed. Check length of master cylinder push rod. Be sure to stake tab socket if required by manufacturer. See Fig. 31-29.

Install booster. Hook up lines. Bleed brakes and test.

An exploded view of a double diaphragm power booster is pictured in Fig. 31-30.

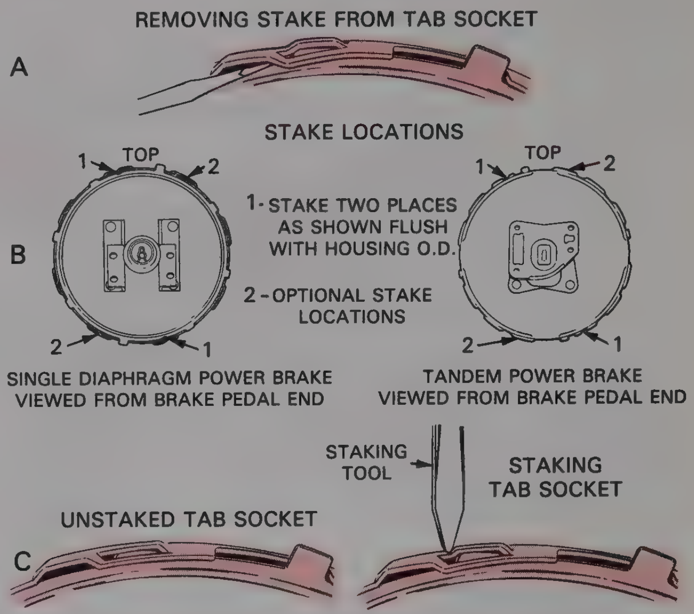

REMOVING STAKE FROM TAB SOCKET
A
STAKE LOCATIONS
B
TOP
1
2
1 - STAKE TWO PLACES AS SHOWN FLUSH WITH HOUSING O.D.
2 - OPTIONAL STAKE LOCATIONS
SINGLE DIAPHRAGM POWER BRAKE VIEWED FROM BRAKE PEDAL END
TANDEM POWER BRAKE VIEWED FROM BRAKE PEDAL END
STAKING TOOL
STAKING TAB SOCKET
UNSTAKED TAB SOCKET
C

Fig. 31-29. A—Removing stake from tab socket. B—Various stake locations on a single and dual diaphragm power brake unit. C—Illustrates an unstaked socket being staked. (Chevrolet)

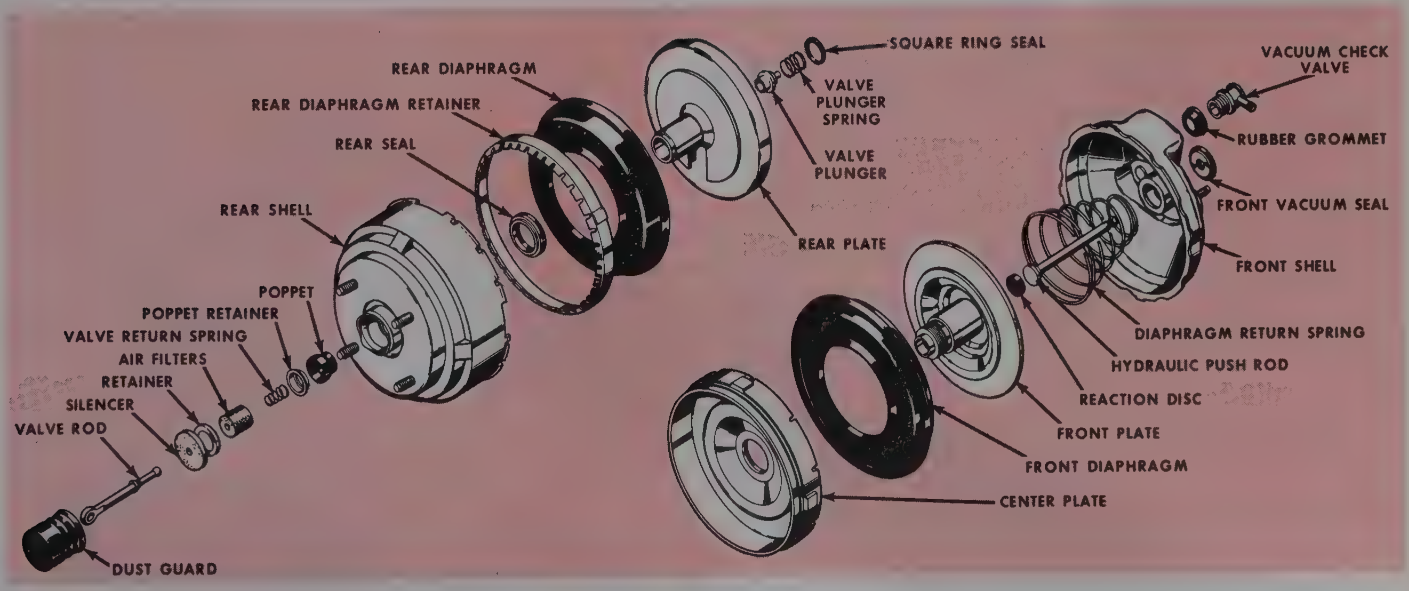

SQUARE RING SEAL
REAR DIAPHRAGM
VACUUM CHECK VALVE
VALVE PLUNGER SPRING
REAR DIAPHRAGM RETAINER
RUBBER GROMMET
REAR SEAL
VALVE PLUNGER
FRONT VACUUM SEAL
REAR SHELL
REAR PLATE
FRONT SHELL
POPPET
POPPET RETAINER
VALVE RETURN SPRING
DIAPHRAGM RETURN SPRING
AIR FILTERS
HYDRAULIC PUSH ROD
RETAINER
SILENCER
REACTION DISC
VALVE ROD
FRONT PLATE
FRONT DIAPHRAGM
CENTER PLATE
DUST GUARD

Fig. 31-30. Exploded view of a double diaphragm power booster. (Pontiac)

NOTE: Many shops do not perform power booster overhaul. They prefer to install new or rebuilt units.

HYDRAULIC POWER BOOSTER

A hydraulically operated unit (also called "Hydro-Boost") is incorporated on some vehicles. The power steering pump is normally used as a source of hydraulic pressure. Other belt driven or electric pumps may also be used.

A Hydro-Boost arrangement consists of a pump, booster, and master cylinder. Fig. 31-31 shows one type of overall system.

Like the vacuum booster, the hydraulic booster is attached to the master cylinder. Depressing the brake pedal actuates the booster valves, which in turn, cause the booster to apply pressure to the master cylinder primary piston. An exploded view of a booster is pictured in Fig. 31-32.

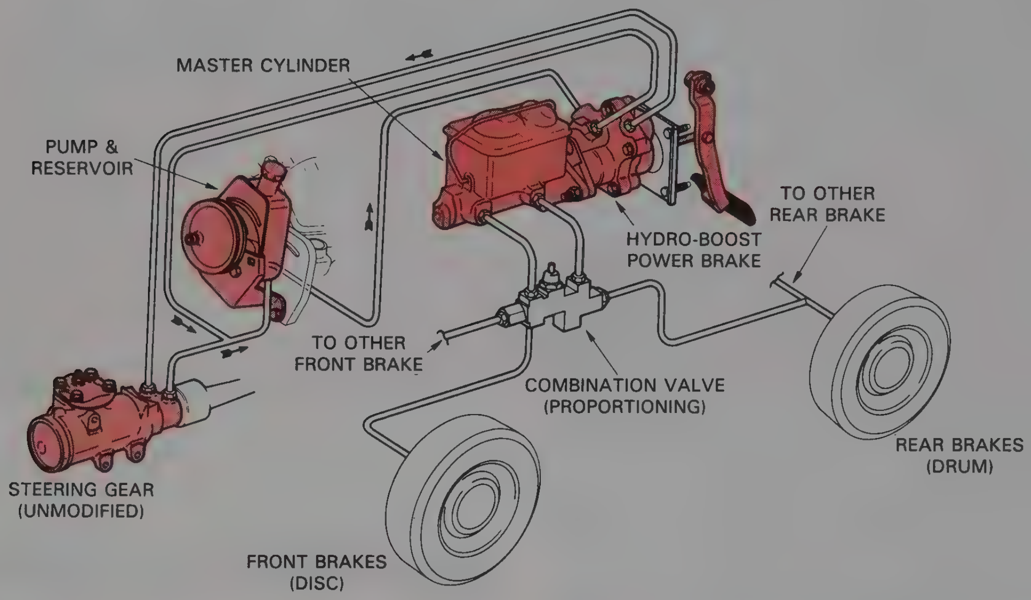

MASTER CYLINDER
PUMP & RESERVOIR
TO OTHER REAR BRAKE
HYDRO-BOOST POWER BRAKE
TO OTHER FRONT BRAKE
COMBINATION VALVE (PROPORTIONING)
REAR BRAKES (DRUM)
STEERING GEAR (UNMODIFIED)
FRONT BRAKES (DISC)

Fig. 31-31. Overall Hydro-Boost system layout. Note hydraulic fluid flow arrows (black). (Bendix)

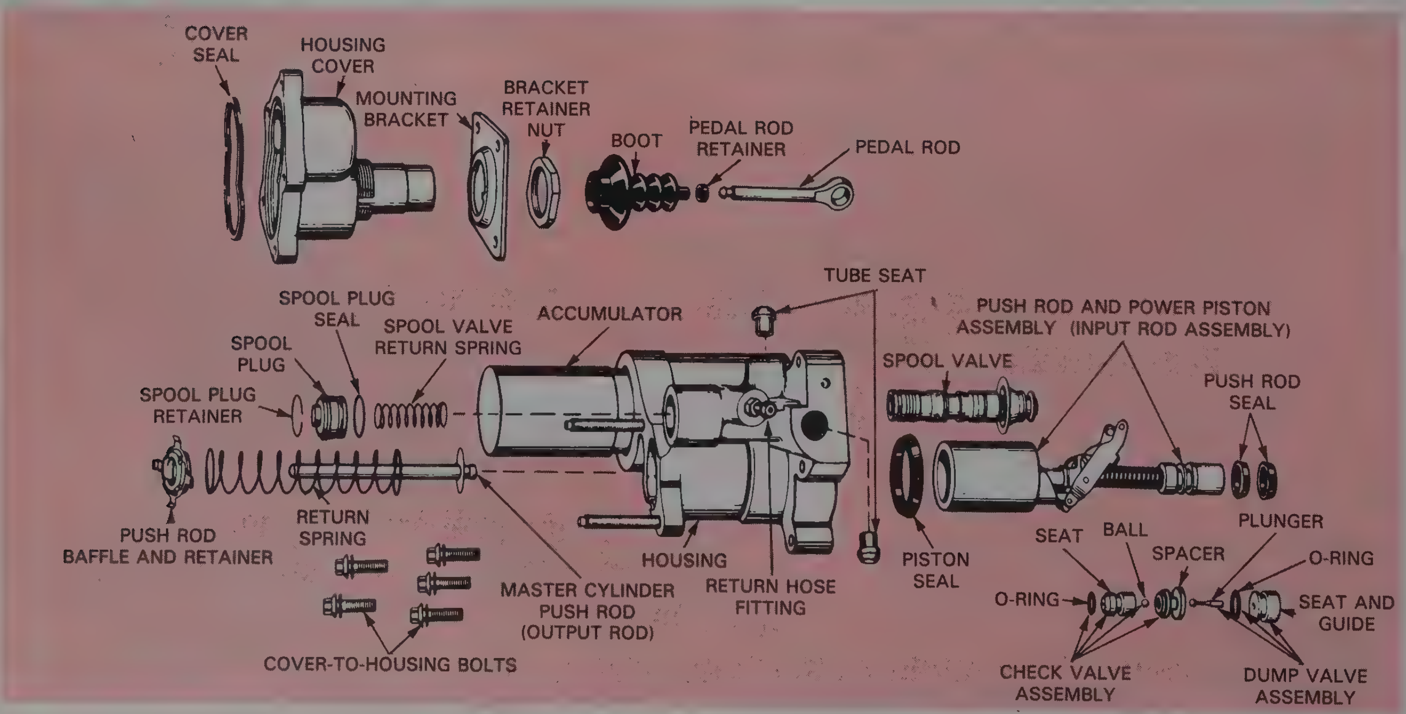

COVER SEAL
HOUSING COVER
MOUNTING BRACKET
BRACKET RETAINER NUT
BOOT
PEDAL ROD RETAINER
PEDAL ROD
TUBE SEAT
SPOOL PLUG SEAL
SPOOL VALVE RETURN SPRING
ACCUMULATOR
PUSH ROD AND POWER PISTON ASSEMBLY (INPUT ROD ASSEMBLY)
SPOOL PLUG
SPOOL VALVE
PUSH ROD SEAL
SPOOL PLUG RETAINER
PUSH ROD BAFFLE AND RETAINER
RETURN SPRING
HOUSING
PISTON SEAL
SEAT
BALL
PLUNGER
SPACER
O-RING
O-RING
SEAT AND GUIDE
MASTER CYLINDER PUSH ROD (OUTPUT ROD)
RETURN HOSE FITTING
COVER-TO-HOUSING BOLTS
CHECK VALVE ASSEMBLY
DUMP VALVE ASSEMBLY

Fig. 31-32. Exploded view of a Hydro-Boost unit. Study parts and their locations. (Bendix)

HYDRO-BOOST — RELEASED POSITION

While in the released position, fluid flow is through the booster power section and on to the power steering gear. No operating pressure is built up in the booster at this time. A booster in the released position can be seen in Fig. 31-33.

HYDRO-BOOST — APPLIED POSITION

As the brake pedal is depressed, the booster input push rod and piston are moved forward, towards the master cylinder. This causes the spool valve to also move forward. This allows more fluid to flow into the cavity behind the power piston. As pressure builds behind the power piston, it moves forward actuating the master cylinder. Fig. 31-34 illustrates a power booster in the applied position.

HYDRO-BOOSTER FAILURE

Most booster units use an ACCUMULATOR. This unit can contain a spring and/or gas under pressure.

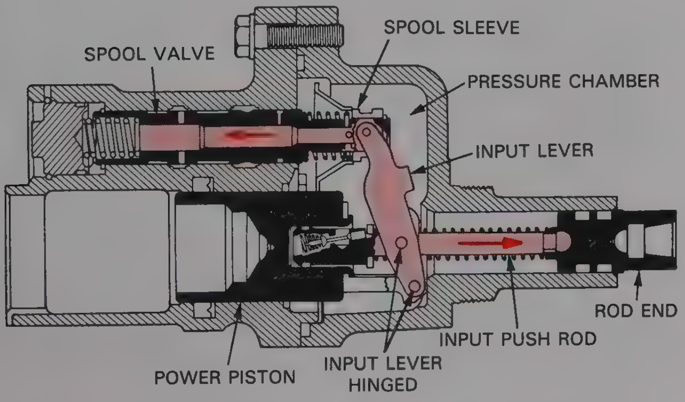


Fig. 31-33. Cross sectional view of one particular Hydro-Boost unit. The booster is in fully released position. (FMC)

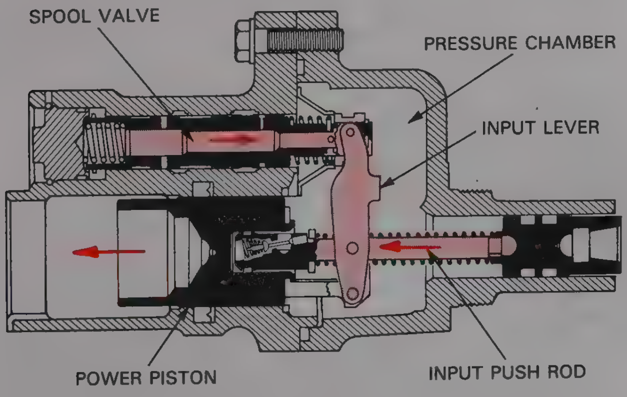


Fig. 31-34. Hydro-Boost in applied position. Input lever has moved spool valve, allowing more pressure in pressure chamber. Power piston is forced forward applying pressure to master cylinder. (FMC)

The accumulator is filled with hydraulic fluid each time the brakes are applied. If the hydraulic power source fails for some reason, the accumulator will provide around three pressure assisted stops. Brakes can also be operated with no power assist, but will require a much firmer pedal pressure.

CAUTION! ACCUMULATORS CONTAIN STRONG SPRINGS AND PRESSURIZED GAS. THEY CAN COME APART WITH LETHAL FORCE. DO NOT APPLY HEAT. FOLLOW MAKER'S RECOMMENDATIONS FOR CORRECT DISPOSAL. DO NOT ATTEMPT ACCUMULATOR SERVICE WITHOUT PROPER TRAINING AND TOOLS.

HYDRO-BOOSTER — SERVICE

The following are general service steps for service of a Hydro-Boost unit. Always follow manufacturer's procedures.

1. Remove Hydro-Boost from vehicle — with or without master cylinder connected. Do not bend or kink steel brake lines.
2. Mount booster on a special holding fixture or clamp in a vise. Usually, the master cylinder end goes up.
3. Remove spool valve plug and retainer. Take out spool valve plug, O-ring(s), spring, and other parts.
4. Remove all remaining parts. Be sure to keep them in order.
5. Clean all parts in denatured alcohol or new, clean power steering fluid. Check valve and bores for scratches or indications of wear. If scratches can be felt with your fingernail, booster unit should be replaced. These units maintain extremely close tolerances and parts are not interchangeable.
6. Reassemble in the reverse order of disassembly. Replace all seals and O-rings. Lubricate all parts with clean power steering fluid as you reassemble.

WHEEL CYLINDERS

Three typical wheel cylinders are shown in Fig. 31-35. Shown in A, the single end type is used one per brake shoe, or in some cases, only one per wheel where one shoe (servo type) is allowed to apply the other. The stepped cylinder, in B, is used to apply a different force to each brake shoe. The most widely used cylinder, C, uses two pistons in a straight cylinder. One other type employs a pierced baffle between the pistons to retard the return of one of the pistons.

WHEEL CYLINDER REMOVAL

Pull the wheel and brake drum. Remove the brake shoes (see Brake Shoe Removal in this chapter). Disconnect the hydraulic hose (front wheel) at the line connection. Then unscrew from the wheel cylinder. At the

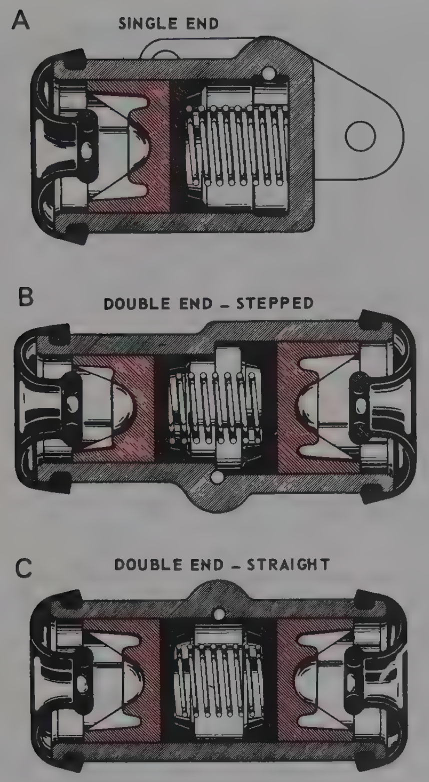

A
SINGLE END
B
DOUBLE END – STEPPED
C
DOUBLE END – STRAIGHT

Fig. 31-35. Typical wheel cylinders. (Bendix)

rear wheel (brake line runs to cylinder—no hose used), loosen the flare nut. Do not bend the brake line out of the way. This can damage the line and make alignment difficult during installation.

Remove the wheel cylinder-to-backing plate fasteners. Remove cylinder. See Fig. 31-36.

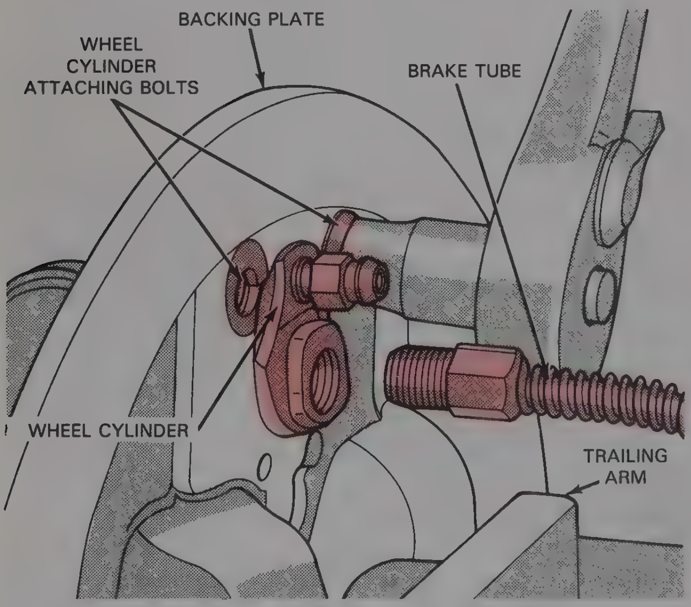

BACKING PLATE
WHEEL CYLINDER ATTACHING BOLTS
BRAKE TUBE
WHEEL CYLINDER
TRAILING ARM

Fig. 31-36. Removing wheel cylinder attaching bolts so cylinder can be removed from backing plate. (Chrysler)

OBSERVE CAUTIONS

When disassembling, repairing, and assembling wheel cylinder, KEEP RUBBER PARTS AWAY FROM OIL AND GREASE. WASH HANDS WITH SOAP AND WATER. USE DENATURED ALCOHOL FOR CLEANING. LUBE PARTS WITH BRAKE FLUID BEFORE REASSEMBLY.

WHEEL CYLINDER REPAIR

Pull the rubber boots free of the cylinder and push the pistons, cups, and spring from the cylinder. Use air on single end cylinders to force the piston free. See Fig. 31-37.

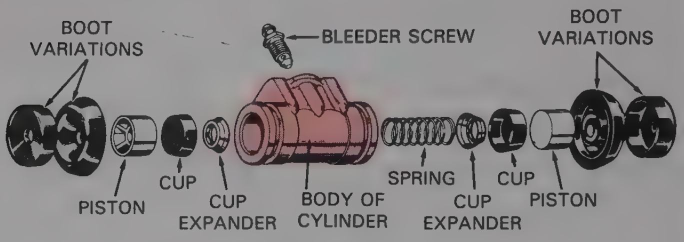

BOOT VARIATIONS
BLEEDER SCREW
BOOT VARIATIONS
PISTON
CUP
CUP EXPANDER
BODY OF CYLINDER
SPRING
CUP EXPANDER
CUP
PISTON

Fig. 31-37. Typical wheel cylinder. (Bendix)

Wash all parts in denatured alcohol. Some wheel cylinder pistons are made of iron and are impregnated with lubricant. Do not wash these pistons; wipe them off. Pistons should not be reused if pitted or scratched.

Aluminum wheel cylinder bodies should be replaced if they are pitted, corroded, or scratched. Clean cast iron cylinders with crocus cloth and inspect. If crocus cloth fails to remove scratches or pitting, light honing (with very fine grit stones) may be used. Use brake fluid for stone lubrication, Fig. 31-38.

Following honing or the use of crocus cloth, scrub with an alcohol soaked rag. Rinse in alcohol. Blow dry. Rinse in fresh alcohol and blow dry again.

NOTE: THE COMPRESSED AIR USED TO BLOW CYLINDERS DRY MUST BE DRY AND FREE OF OIL. IF IT IS NOT, FINISH CLEANING WITH AN ALCOHOL RINSE AND ALLOW PARTS TO AIR DRY.

If the wheel cylinder has a special glassy, rolled finish, do not attempt honing.

Inspect cylinder. The finish must be free of scoring and pitting. A slight pitting in the very center of the cylinder is permissible as long as it is not on that part of the cylinder that engages the rubber cups. If doubtful, discard the cylinder.

Many shops will not overhaul wheel cylinders. They feel that the cost of the labor involved, along with a possible reduction in the service life of used cylinders, does not warrant such work. When a cylinder is defective, it is replaced with a new one.

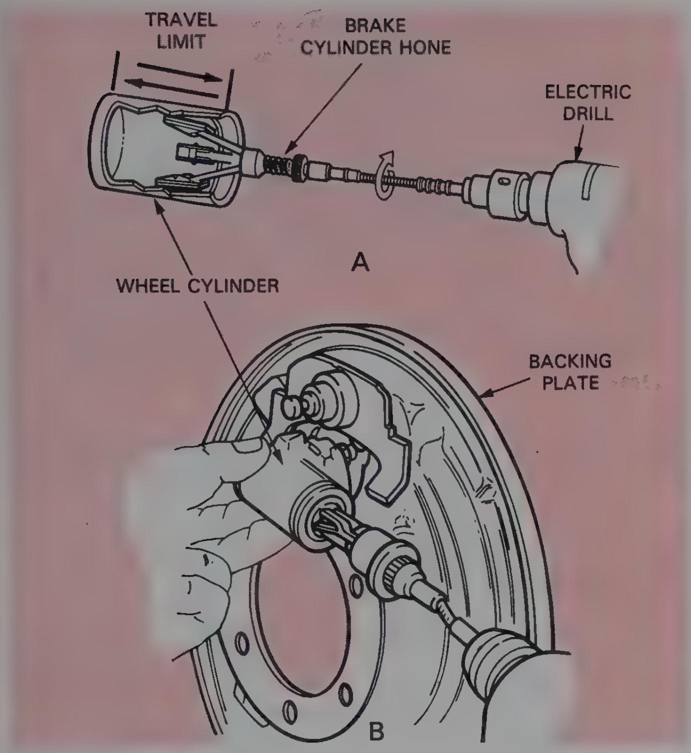


Fig. 31-38. Honing a wheel cylinder. A—Hone in place. Note stone travel limit. DO NOT push stones all the way through or pull completely out while turning. Compress spring-loaded fingers and insert before starting to turn hone. B—Wheel cylinder being honed while mounted on backing plate. (Niehoff)

Check the clearance between the piston and cylinder wall. It must not exceed .005 in. (0.127 mm) for cylinders 1 in. (25.4 mm) or less in diameter, or .007 in. (0.178 mm) for cylinders exceeding 1 in. (25.4 mm). Use a No-Go gauge or a feeler gauge, D and E, Fig. 31-39.

Pistons must be free of corrosion, scoring, or flat spots.

Coat cylinder, new cups, and pistons with brake fluid and assemble.

MAKE CERTAIN OPEN SIDE OF CUPS FACE INWARD. IF CUP EXPANDERS ARE USED, THEY MUST BE IN PLACE. DO NOT DAMAGE CUPS WHEN STARTING INTO CYLINDER. DO NOT FORCE CUPS OVER CENTER PORTS.

Snap the end boots into place to hold the pistons in the cylinder. Use a cylinder clamp if needed. Install cylinder on backing plate. Connect brake line. Install shoes and drum. Bleed brakes.

The major steps in wheel cylinder reconditioning are illustrated in Fig. 31-39.

Always remove, disassemble, and clean wheel cylinders when the brakes are relined. Relining the brakes, in some designs, can force the wheel cylinder pistons deeper into the cylinder. In the event corrosion, rust, or gum has formed between the cups, forcing the pistons inward would cause the cups to operate on the rough surface. Scoring and leakage will soon follow. Always remove, clean, and install kits in all wheel cylinders at the time of brake relining. Replace cylinders if needed.

SERVO BRAKE SHOE DESIGN

Brake shoes can be arranged so that one shoe helps to apply the other. This setup is referred to as a SERVO brake. Study A, in Fig. 31-40. Note that when shoes

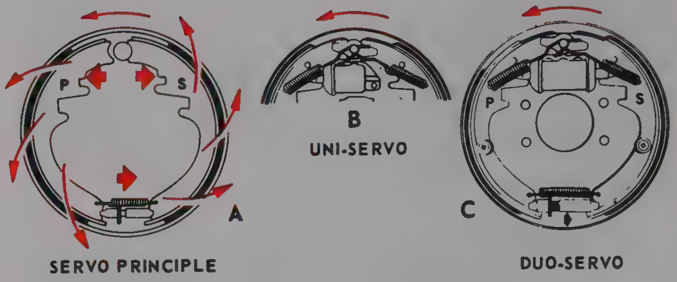


Fig. 31-40. Single-anchor, self-energizing, servo brake arrangement.

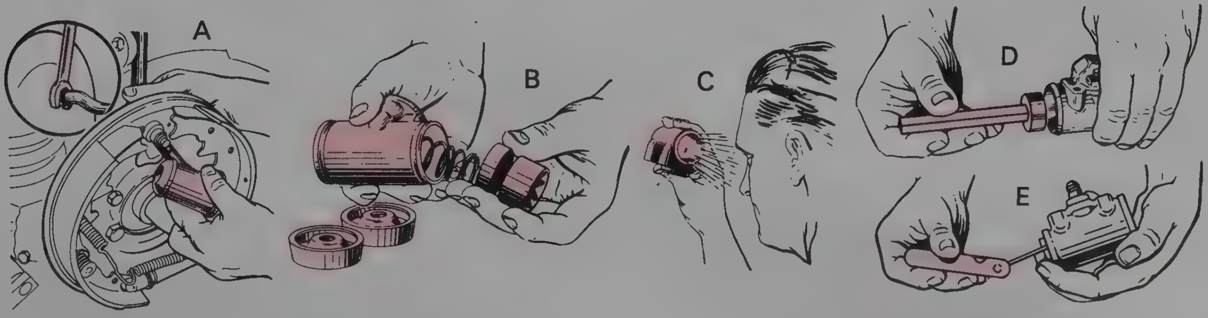


Fig. 31-39. Some major steps in wheel cylinder reconditioning. A—Remove cylinder. B—Disassemble and clean. C—Inspect cylinder. D—Checking cylinder with No-Go gauge. E—Checking cylinder-to-piston clearance with feeler gauge. (Wagner)

are forced into contact with the drum, the primary (P) shoe is carried around with the drum. This jams the secondary shoe(s) against the drum and anchor pin.

These shoes are also self-energizing. The shoe free end is forced into contact with the revolving drum. The free end moves toward the anchored end of the shoe, creating friction that tends to force the shoe even tighter against the drum. Both shoes in A, Fig. 31-40, are self-energizing.

B, Fig. 31-40, illustrates a servo brake with one single end wheel cylinder. This arrangement is referred to as uni-servo. C shows the same setup as A, except the springs and wheel cylinder have been added. This is called a duo-servo, self-energizing brake arrangement.

NON-SERVO BRAKE

Since each shoe in A, Fig. 31-41, is anchored, it is impossible for one shoe to assist in the application of the other. This brake is called a NON-SERVO brake. The forward shoe is self-energizing; the reverse shoe is not (drum turning in direction of arrow). B shows the same setup but with wheel cylinder and spring added. C uses a single-end cylinder for each shoe. Note that both shoes are self-energizing. Both B and C are double-anchor, non-servo brakes.

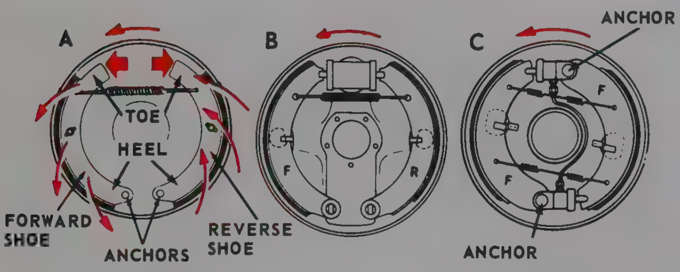


Fig. 31-41. Double-anchor, non-servo brake design.

OTHER TYPES

Fig. 31-42 illustrates three other brake shoe and anchor arrangements. A is a single-anchor, non-servo. B is the huck type brake, single-anchor, non-servo. C is the total-contact, center-plane, non-servo brake.

SELF-CENTERING BRAKES

Some brake shoes will center themselves in the drum when applied. To do this, they must be free to move up and down as well as outward. Double-anchor brakes shown in A, B, and C, Fig. 31-41 are NOT self-centering.

The single anchor brakes illustrated in A and B, Fig. 31-42 are self-centering in that the anchored ends are free to move up or down.

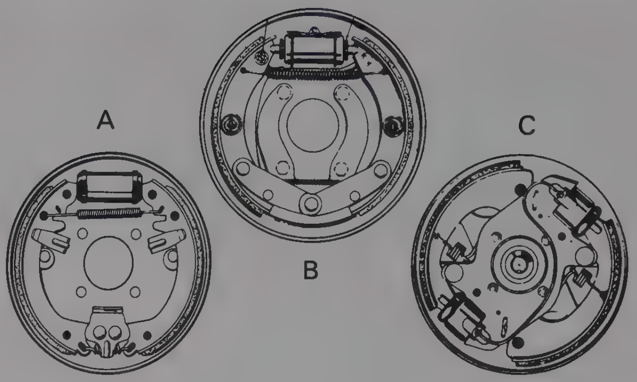


Fig. 31-42. Other brake types. In that anchored ends of these shoes are free to move up and down, they are all self-centering. (Wagner)

IN WIDESPREAD USE

The drum brake design in wide use today is the single-anchor, duo-servo. The anchor is fixed (cannot be moved). This automatically centers the shoes. The use of a ratcheting device makes the brake self-adjusting, Fig. 31-43.

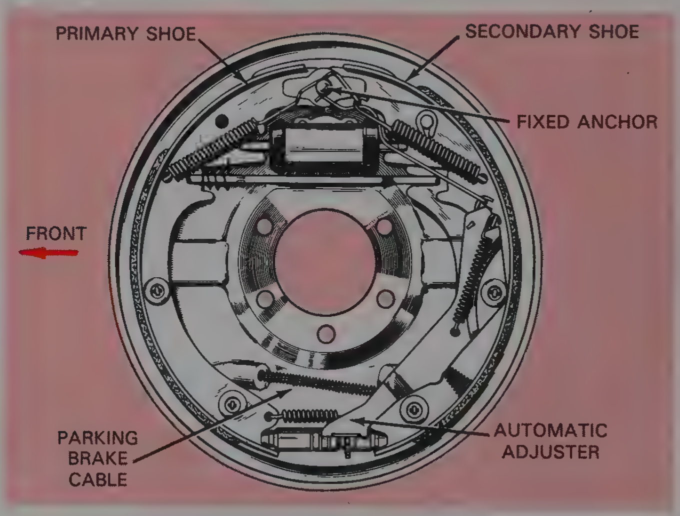
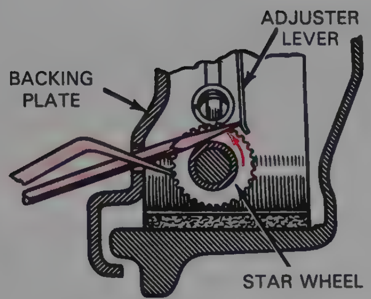


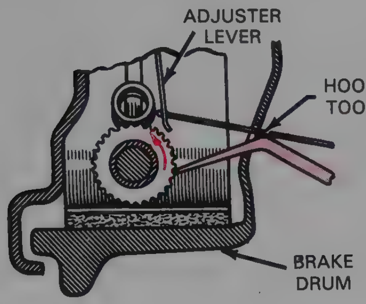
Fig. 31-43. Fixed single-anchor, duo-servo, self-adjusting brake design. (Bendix)

BRAKE SHOE REMOVAL

Pull the wheel and drum. Parking brake must be off to remove rear drums. If the brake shoes are too tight to pull the drum, back off the adjustment. On self-adjusting brakes, pass a thin screwdriver through the adjustment slot in the backing plate. Hold the adjuster lever free while the adjuster wheel (star wheel) is loosened. If adjustment is through a slot in the brake drum, a hook may be used to pull the adjuster lever free, Fig. 31-44.



BACKING OFF ON ADJUSTING SCREW
(ACCESS SLOT IN BACKING PLATE)



BACKING OFF ON ADJUSTING SCREW
(ACCESS SLOT IN BRAKE DRUM)

Fig. 31-44. Adjuster lever must be held out of the way to back off adjuster star wheel.

STUDY THE ARRANGEMENT

Before attempting to remove the shoes, study the arrangement of the brake parts. Note the color of the springs; where they are connected and in what order; how hold-downs are installed; etc. This procedure will help during assembly.

CLAMP THE WHEEL CYLINDER

Install a wheel cylinder clamp to prevent the pistons from popping out of the cylinder. Leave the clamp in place until the shoes are reinstalled. See Fig. 31-45.

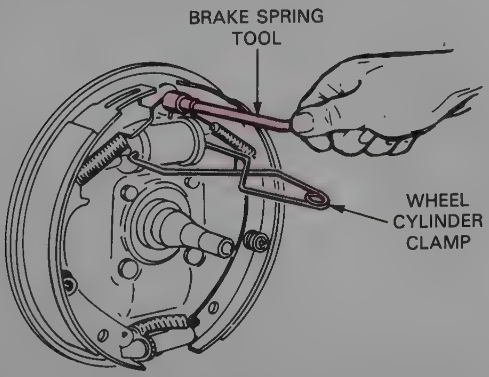


Fig. 31-45. Brake spring tool being used to remove shoe return springs. Note cylinder clamp. (FMC)

REMOVE THE SHOES

Use brake spring pliers to remove the retracting springs, Fig. 31-45. A number of spring arrangements for single-anchor, duo-servo brakes are shown in Fig. 31-46.

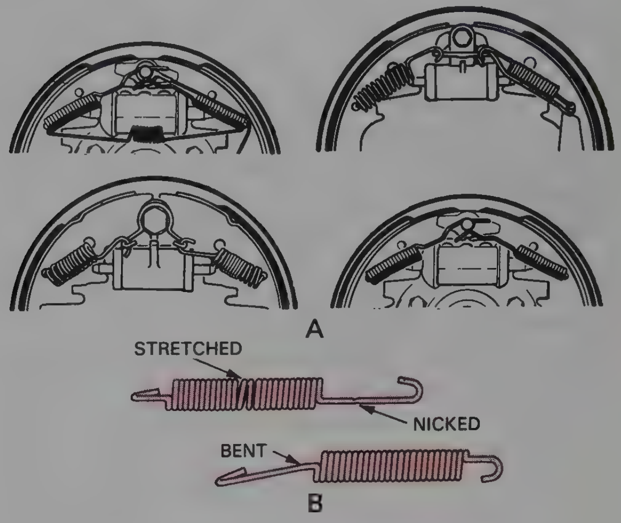


Fig. 31-46. A—Some single-anchor, duo-servo shoe retracting spring arrangements. B—These retracting springs are unsuited for further use.

Remove the shoe hold-downs, Fig. 31-47. If the shoes are fixed to anchors, remove anchors or fasteners as needed. As parts are removed, lay out in proper order. Keep parts for each wheel in one group. Clean and inspect all parts. SEE ASBESTOS WARNING EARLIER IN CHAPTER.

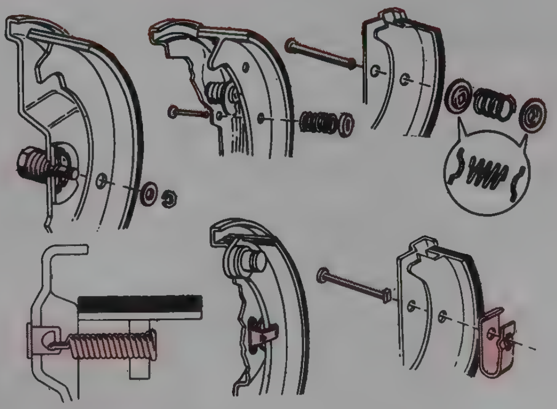


Fig. 31-47. Various types of brake shoe hold-downs.

Check springs carefully to make certain they are in good condition. Damaged springs may be recognized by discoloration, stretched areas, nicks, and end hook opening. See Fig. 31-46.

BRAKE SHOE RELINING

Most shops do not have the facilities to bond lining to the shoes. Instead, they buy either new or relined shoes.

Rivets are used to attach the lining to some shoes. To rivet new lining to the shoes, use the following procedure:

Inspect each shoe for signs of damage. Look for twisting, cracked web, broken welds, worn anchor contact area, rim scoring, and edge wear.

Minor rim scoring covering a distance not exceeding 2 in. (51 mm) will not require rejecting the shoe. Discard all shoes not passing inspection, Fig. 31-48, A.

Remove the lining by drilling out the rivets. Careless use of a rivet removal punch can damage the shoe. Wire brush the shoe, as in B, Fig. 31-48. Then, clean, rinse, and blow dry.

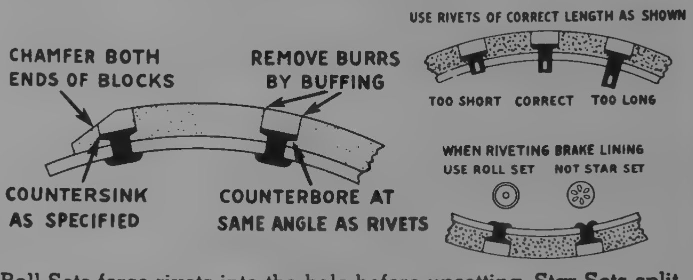
Place the new lining on the shoe. Make certain the primary lining is applied to the primary shoe, secondary to secondary. Use a lining clamp, C, Fig. 31-48, to force the lining tightly against the shoe. Rivet the two ends. Remove clamp and install remaining rivets. If no clamp is used, start riveting in the center, D, and work toward the ends. If needed, use a shim under lining, E.

Use a roll rivet set; not the star design as it will split the rivet. The rivet head angle should match the hole counterbore. The rivet should be long enough so that the solid portion just extends through the shoe rim. Counterbore should extend about 2/3 of the way through the lining.

Rivets should be set tightly but not so tight that they crack the lining. See F, Fig. 31-48.

When all rivets are set, check to see that the lining is snug against the shoe. Slide a feeler gauge (.008 in. or 0.20 mm for wire-back, .006 in. or 0.15 mm for other types) between the shoe rim and lining. Refer to G. The gauge should not penetrate beyond the rivets. Check each rivet to see that it is square and properly set. Grind shoe, H.

Fig. 31-49 shows properly installed rivets.


USE RIVETS OF CORRECT LENGTH AS SHOWN
CHAMFER BOTH ENDS OF BLOCKS
REMOVE BURRS BY BUFFING
TOO SHORT
CORRECT
TOO LONG
WHEN RIVETING BRAKE LINING
USE ROLL SET
NOT STAR SET
COUNTERSINK AS SPECIFIED
COUNTERBORE AT SAME ANGLE AS RIVETS

Roll Sets force rivets into the hole before upsetting. Star Sets split the tube and rivets do not fill the hole, as shown above.

Fig. 31-49. Proper riveting is a must. (Grey-Rock)

USE QUALITY LINING

Always use high quality brake lining, designed for the job. Quality lining is stronger. It will wear longer and provide the proper coefficient of friction for good brake action.

LINING MUST BE GROUND FOR PROPER FIT

Slight variations in shoe contour and lining thickness require that the lining be ground following installation on the shoe.

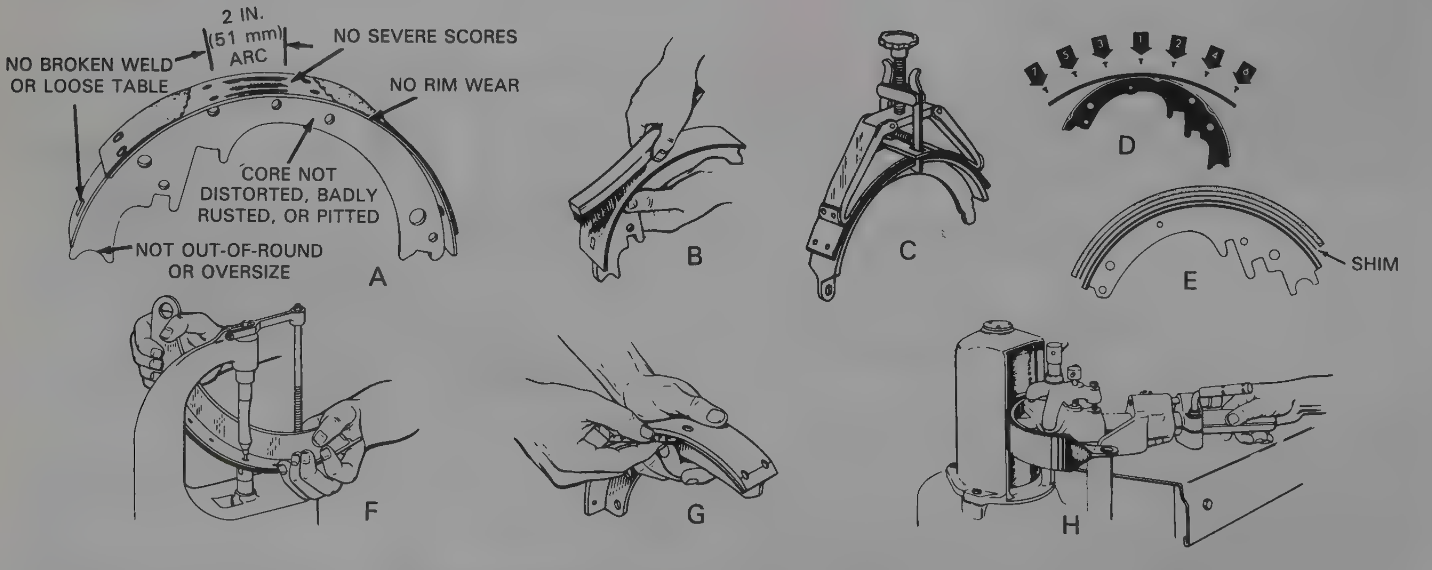

2 IN.
(51 mm)
ARC
NO BROKEN WELD OR LOOSE TABLE
NO SEVERE SCORES
NO RIM WEAR
CORE NOT DISTORTED, BADLY RUSTED, OR PITTED
NOT OUT-OF-ROUND OR OVERSIZE
A
B
C
7
5
3
1
2
4
6
D
E
SHIM
F
G
H

Fig. 31-48. Some major steps in riveting new lining to a brake shoe. A—Inspect for shoe problems. B—Clean shoe and inspect. C—Hold lining with clamp and rivet ends. D—With no clamp, rivet in center and work toward ends. E—Use shim stock if needed. F—Rivet firmly but do not use excessive pressure. Use a roll set. G—Check lining-to-shoe fit with feeler gauge. H—Grind shoe to correct radius. (Wagner)

The shoe is placed in a special grinder and adjusted. The shoe is swung back and forth across the grinder face. This grinds the lining to the proper contour and will guarantee that the lining is square with the shoe. Fig. 31-50 shows one type of brake shoe grinder.

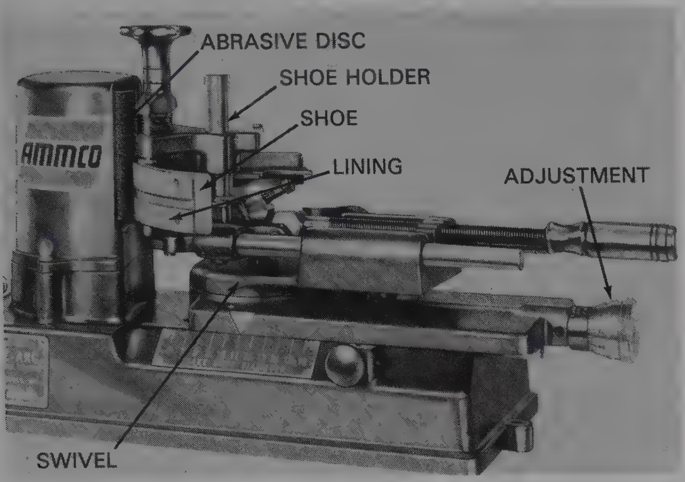

ABRASIVE DISC
SHOE HOLDER
SHOE
AMMCO
LINING
ADJUSTMENT
SWIVEL

Fig. 31-50. One type of brake shoe grinder. Always grind lining for best results. Be sure shoe is clamped firmly and aligned properly. Dust collection system is not shown. (Ammco)

Another type grinds the shoes after they are installed on the backing plate.

Remember the cancer danger of inhaling asbestos. Use the vacuum unit on the grinder.

CONCENTRIC GRINDING

Concentric grinding of the shoe produces a perfect fit between the lining and brake drum. Concentric grinding involves setting the grinder to grind the lining to the SAME diameter as the brake drum.

Concentric ground shoes are seldom used as they tend to cause pull, squeal, etc., during the break-in period. See A, Fig. 31-51.

ECCENTRIC (CONTOUR) GRINDING

Eccentric or contour grinding involves grinding the shoe to a smaller diameter than the brake drum. This allows the lining to fit against the drum with a slight clearance at each end. Brake action during break-in is greatly improved by this method of grinding. Most makers specify contour grinding.

For non-servo brakes, the grinder is set to grind the shoes .020 to .030 in. (0.51 to 0.76 mm) under drum diameter. This will give a .005 to .007 in. (0.13 to 0.17 mm) clearance at each end of the shoe, B, Fig. 31-51.

For servo brakes, the shoes are usually ground as much as .040-.050 in. (1.02-1.27 mm) under drum diameter to give end clearances of from .010-.0125 in. (0.25-0.317 mm). See C, Fig. 31-51.

If the grinder markings refer to brake drum radius instead of diameter, cut contour grinding undersize specifications in half. For example, instead of setting for .030 in. (0.76 mm) under, set for .015 in. (0.38 mm) undersize. Follow manufacturer's specs.

INSTALLING BRAKE SHOES

Clean the backing plate and torque plate mounting fasteners. Sand the shoe pads (raised portions of backing plate used to support shoes). Coat with a film of high temperature grease, as in Fig. 31-52.

Clean and back off shoe adjuster cams on the backing plate. This will allow the drum to clear the new, thicker lining, A, B, Fig. 31-53.

Place a small amount of high temperature grease on the adjuster screw threads and on the ends where they contact the brake shoes. Lubricate between hold-down and shoe surface and where the wheel cylinder links or push rods contact the shoes. USE SPECIAL BRAKE HIGH TEMPERATURE LUBE AND USE SPARINGLY. NEVER USE OIL OR OTHER GREASES.

Install shoes, being careful to place the primary and secondary shoes in their proper positions. On

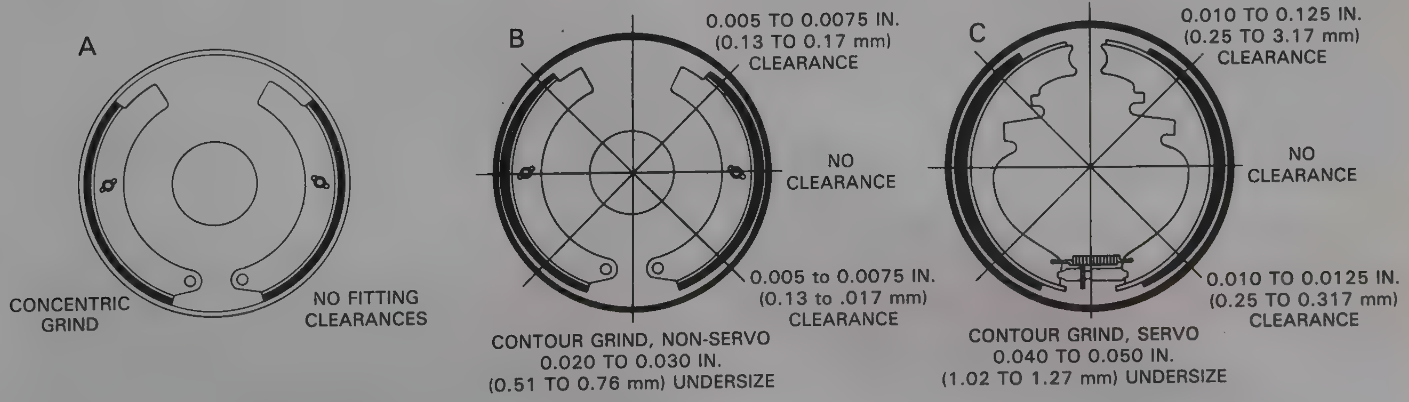

A
CONCENTRIC GRIND
NO FITTING CLEARANCES
B
0.005 TO 0.0075 IN. (0.13 TO 0.17 mm) CLEARANCE
NO CLEARANCE
0.005 to 0.0075 IN. (0.13 to .017 mm) CLEARANCE
CONTOUR GRIND, NON-SERVO 0.020 TO 0.030 IN. (0.51 TO 0.76 mm) UNDERSIZE
C
0.010 TO 0.125 IN. (0.25 TO 3.17 mm) CLEARANCE
NO CLEARANCE
0.010 TO 0.0125 IN. (0.25 TO 0.317 mm) CLEARANCE
CONTOUR GRIND, SERVO 0.040 TO 0.050 IN. (1.02 TO 1.27 mm) UNDERSIZE

Fig. 31-51. Concentric and eccentric (contour) grinding practices. (Wagner)

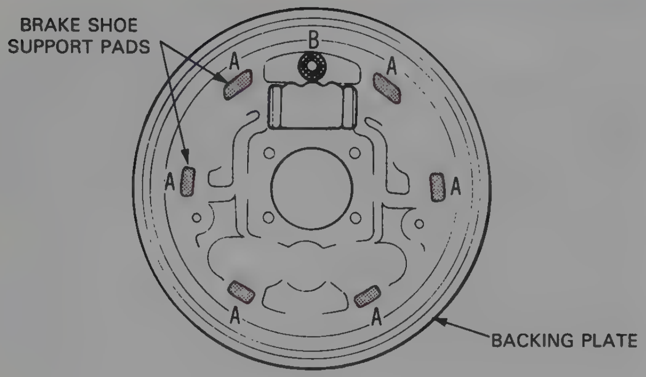


Fig. 31-52. A—Clean and lubricate brake shoe support pads. B—Lightly grease anchor if recommended. (Plymouth)

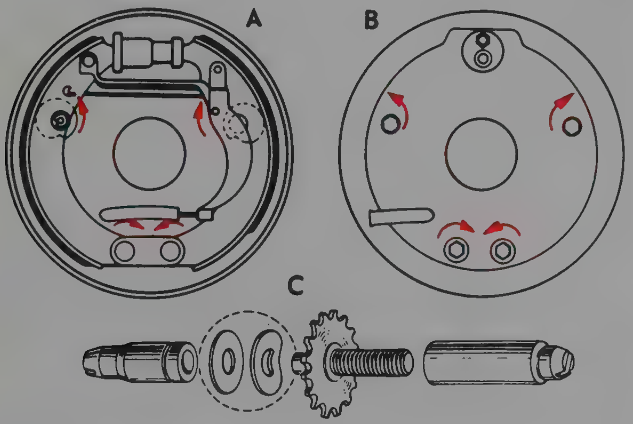


Fig. 31-53. Back off adjuster cams, A and B, to provide clearance required to install brake drum. Clean, lubricate, and collapse adjuster type, shown in C. (Wagner)

single-anchor, duo-servo applications, the primary shoe will have the short lining and will face the front of the car. The primary shoe will be the first shoe encountered moving away from the wheel cylinder in the direction of forward wheel rotation.

Install hold-downs and retracting springs. Make certain springs are in the correct position and hooked in the proper spot, Figs. 31-46 and 31-47. Use brake spring pliers to avoid damage to the spring, Fig. 31-54.

When installed (parking brake lever and cable, plus automatic adjusters, where used, must be in place), rap the shoe assembly back and forth to check for freedom of movement. Recheck entire assembly. Install brake drum and adjust shoes.

KEEP GREASE AND OIL FROM LINING

AVOID TOUCHING THE LINING WITH THE FINGERS AS MUCH AS POSSIBLE. KEEP HANDS FREE OF GREASE AND OIL. REMEMBER THAT EVEN THE SLIGHTEST BIT OF OIL ON THE LINING WILL RUIN THE BRAKE JOB.

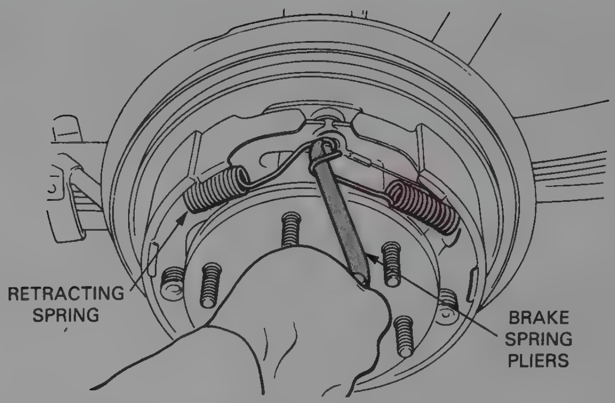


Fig. 31-54. Mounting a retracting spring with brake spring pliers. (Dodge)

PARTS MUST BE IN CORRECT POSITION

The shoes must be in their correct positions. The star wheel must face the adjustment slot in the backing plate. Self-adjusters, where used, must be installed on the correct side of the car.

MINOR BRAKE SHOE ADJUSTMENT

A minor brake adjustment means adjusting the shoes toward the drum to make up for lining wear. On non-self-adjusting systems, several minor adjustments will be needed before the shoes need relining.

With the wheel free of the ground, parking brake disconnected, remove the star wheel adjustment slot cover. It may be in backing plate or drum. With a brake adjusting tool, turn the adjusting star wheel in the direction that will expand the shoes. While turning wheel, revolve the tire in the direction of forward travel. Continue turning the star wheel until a firm drag is felt when attempting to rotate the tire.

Rap the backing plate with a rubber mallet and make several firm brake applications to help center the shoes (self-centering shoes only). If this frees wheel, adjust shoes outward again until a firm drag is encountered. At this point, back off the adjuster star wheel the specified number of clicks. If no manufacturer's specifications are available, back off until wheel just runs free and then back off four or five clicks more to provide running clearance. Refer to Fig. 31-55.

In cases where cams are used, Fig. 31-53, adjust until a firm drag is felt. Then move back until wheel spins freely.

CAUTION: DO NOT ADJUST BRAKES TOO CLOSE. DO NOT TRY TO GET THE LINING-TO-DRUM CLEARANCE TOO SMALL IN AN ENDEAVOR TO SECURE AN EXTRA HIGH PEDAL. THE BRAKES WILL DRAG, HEAT UP, AND LOCK. THE LINING WILL BE CHARRED AND RENDERED USELESS.

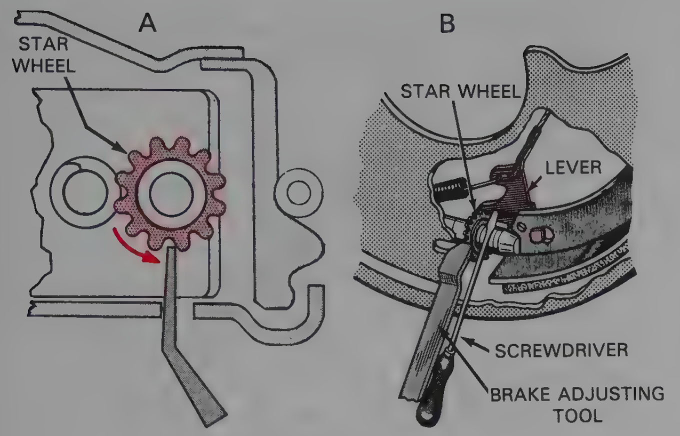

A
STAR WHEEL
B
STAR WHEEL
LEVER
SCREWDRIVER
BRAKE ADJUSTING TOOL

Fig. 31-55. A—Adjusting brakes by turning star wheel. B—Automatic adjusting lever must be held out of way to permit star wheel to be turned.

MAJOR BRAKE SHOE ADJUSTMENT

A major brake adjustment consists of centering the shoes in the drum as well as adjusting lining clearance as in the minor adjustment. Shoes should be checked for correct centering following relining or any time the anchors are disturbed.

Obviously, self-centering brakes will not need the major adjustment.

When shoes are not centered in relationship to the drum, full shoe contact cannot be obtained. This will give poor brake performance and rapid wear. Fig. 31-56 illustrates proper and improper shoe centering.

Although double-anchor shoes, as illustrated in Fig. 31-56, can be adjusted without the use of a gauge, the process is time consuming. Unless performed exactly right, it will produce poor brake performance. These setups are best centered by using a cutaway dummy drum or by using a special gauge attached to the spindle. The gauge is turned and the clearance between the gauge and lining is measured with a feeler gauge. Anchors and adjusting cams are turned until the shoes are centered and the correct clearance exists.

Anchors are generally marked with a dot or an arrow to indicate the high portion of the anchor eccentric.

Two types of single-anchor setups, as well as a single-anchor, self-centering brake, are illustrated in Fig. 31-57. The anchor in A is the eccentric type and is turned to center the shoes. The anchor in B is slotted and is tapped up or down for centering. The anchor in C is self-centering. The arrow on the block (convex side) must face the primary shoe. Another type, not shown, uses a fixed anchor that is held to exacting location tolerances. The shoes, when in proper condition, will center automatically when mounted.

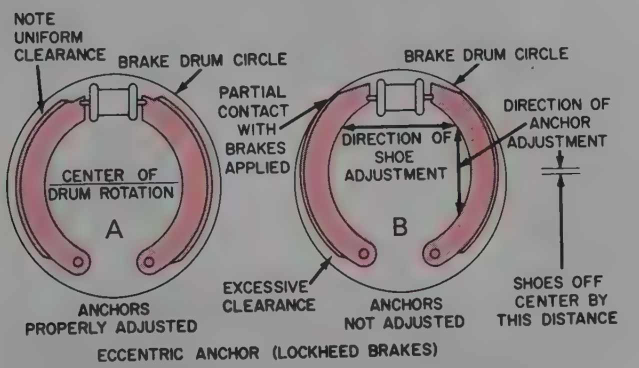

NOTE UNIFORM CLEARANCE
BRAKE DRUM CIRCLE
PARTIAL CONTACT WITH BRAKES APPLIED
BRAKE DRUM CIRCLE
DIRECTION OF ANCHOR ADJUSTMENT
DIRECTION OF SHOE ADJUSTMENT
CENTER OF DRUM ROTATION
A
B
EXCESSIVE CLEARANCE
ANCHORS PROPERLY ADJUSTED
ANCHORS NOT ADJUSTED
SHOES OFF CENTER BY THIS DISTANCE
ECCENTRIC ANCHOR (LOCKHEED BRAKES)

Fig. 31-56. Brake shoes must be properly centered. A—Anchors are adjusted correctly. B—Anchor not properly centered.

CENTERING SHOES — SINGLE SLIDING ANCHOR

Clean around anchor nut. Loosen nut one turn. If of two point design, loosen both nuts. Turn wheel (tire) in the direction of forward motion. While turning, expand the brake shoes outward until a heavy drag is encountered. Use a small ball peen hammer and rap the anchor and backing plate to center shoes.

If the drag is relieved, repeat the process until tapping no longer reduces the drag. At this point, torque the anchor nut and back off the shoes the specified number of notches (wheel must spin freely with no drag). If, after backing off the required number of notches, there is a slight drag, rap the backing plate and apply brake. If this does not free the wheel, back off until drag is gone, B, Fig. 31-57.

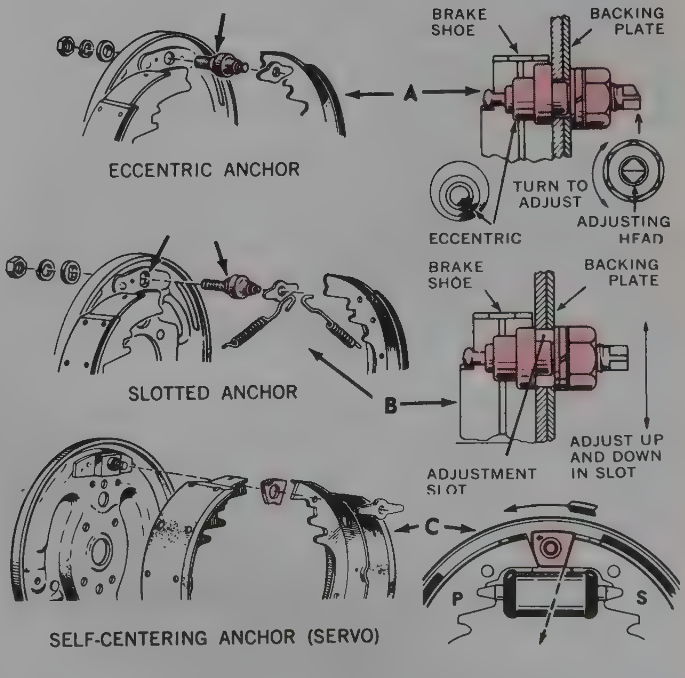

BRAKE SHOE
BACKING PLATE
A
ECCENTRIC ANCHOR
TURN TO ADJUST
ADJUSTING HEAD
ECCENTRIC
BRAKE SHOE
BACKING PLATE
SLOTTED ANCHOR
B
ADJUST UP AND DOWN IN SLOT
ADJUSTMENT SLOT
C
P
S
SELF-CENTERING ANCHOR (SERVO)

Fig. 31-57. Single anchor designs. A and B—Anchors must be adjusted to center shoes. C—Anchor is fixed. (Wagner)

CENTERING SHOES — SINGLE ECCENTRIC ANCHOR

Loosen anchor nut one-half turn. While spinning wheel, adjust shoes outward until a moderate drag is felt. Adjust the anchor up or down (turning top of anchor in direction of forward motion raises shoes) until the drag is relieved. Repeat the process until further adjustment of the anchor no longer affects the drag.

Torque anchor nut and back off shoes until wheel just spins freely. Apply the brake and recheck for free operation. Look at A, Fig. 31-57.

SHOES MUST BE IN CONTACT WITH ANCHOR WHEN CENTERING

When centering the shoes using the single eccentric or sliding anchor, make certain that the parking brake is fully released. Brake pedal free travel must also be correct so that the shoe heel ends rest firmly against the anchor pin. The end of the shoe contacting the anchor is referred to as the heel end; the other, the toe.

ANCHORS DO NOT ALWAYS NEED ADJUSTMENT

If the lining on the old shoes was worn properly and if the new lining is eccentric ground, the anchors will generally not need adjusting. If concentric ground lining is used, anchors must be adjusted to center shoes.

INITIAL SHOE ADJUSTMENT — SELF-ADJUSTING BRAKES (GAUGE METHOD)

Brakes with self-adjusting shoes need only an initial adjustment following the installation of new shoes. Normally, the automatic adjuster will then maintain proper lining-to-drum clearance for the life of the lining.

Release the parking brake and slack off the cable so that both shoes are in firm contact with anchor pin.

Using a special gauge, adjust to brake drum diameter. Lock gauge securely, Fig. 31-58.

Expand the shoes outward (hold lever free of star wheel to prevent burring wheel) until they just fit in the opposite side of the adjusting gauge. See Figs. 31-59 and 31-60.

Install the drums and wheels. Start the car and make a series of stops in reverse. This causes the brake shoes to stick to the drum and follow it around far enough to activate the automatic adjuster. Repeat reverse stops until a full pedal is attained.

INITIAL ADJUSTMENT — SELF-ADJUSTING BRAKES (HAND METHOD)

If no setting gauge is available, install the drum. Turn the star wheel until a firm drag is felt when turning

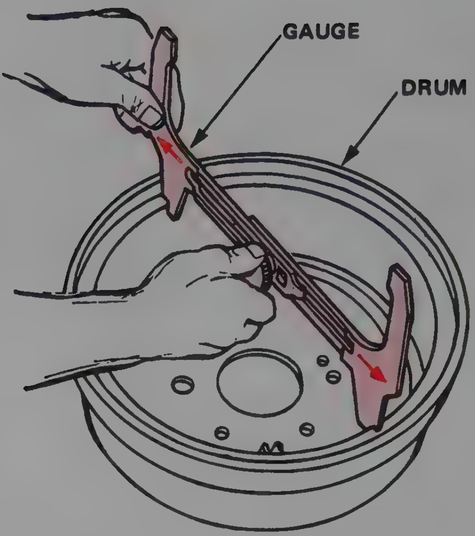


Fig. 31-58. Adjusting special gauge to fit inside brake drum diameter. Lock securely. (Bendix)

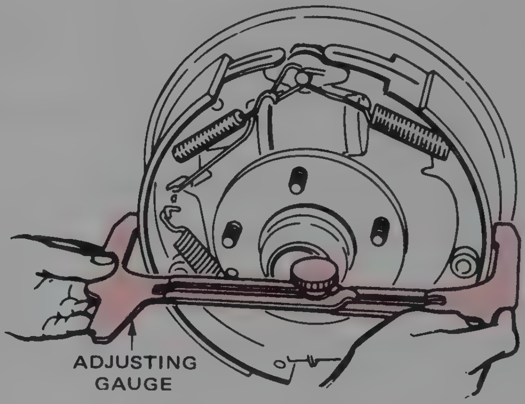


Fig. 31-59. Adjusting shoes to gauge. Check in several directions. (Bendix)

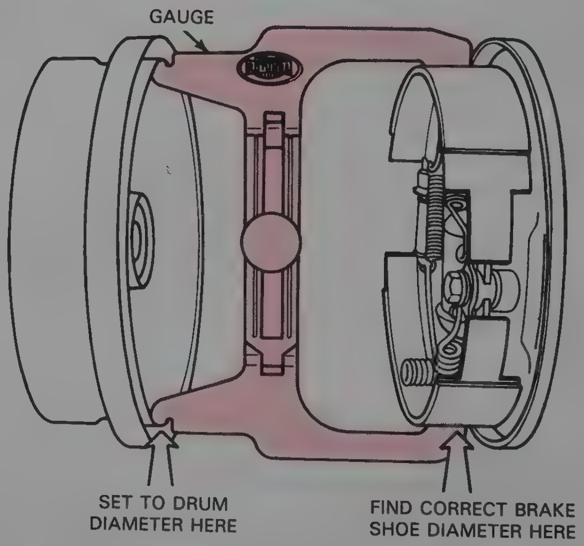

GAUGE
SET TO DRUM DIAMETER HERE
FIND CORRECT BRAKE SHOE DIAMETER HERE

Fig. 31-60. Brake shoe adjusting gauge. Set gauge to drum. Then adjust shoes to fit. (Ford)

the wheel (tire). While holding the adjuster lever out of the way, Fig. 31-61, back off the star wheel about 30 notches.

Make reverse stops until a full pedal is secured.

NOTE: Some cars do not have an opening in front of the star wheel. Careful inspection will reveal a slug (metal still in opening) that must be punched out to form the opening. These slugs can be in the backing plate or in the face of the brake drum itself. When finished with adjustment, fill slot with recommended slot plug.

CAUTION! If slug is knocked out with wheel and drum installed, remove wheel and drum and discard slug. NEVER leave it inside.

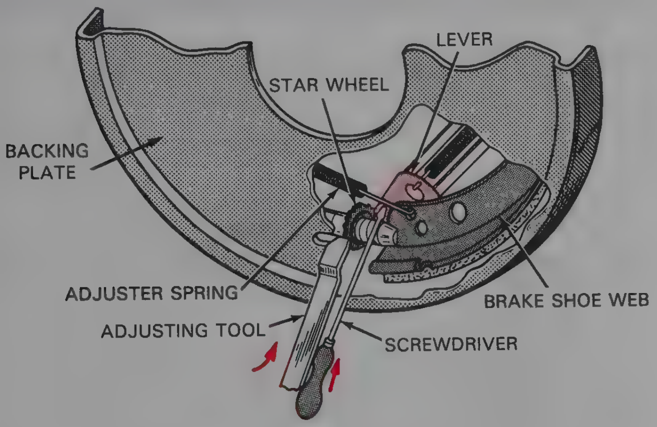


Fig. 31-61. Holding adjuster lever out of the way while turning star wheel. (Chrysler)

CLEAN BRAKE DRUM

Wash the brake dust from the drum. If grease or oil is present, remove with cleaning solvent. Blow dry. Wipe drum braking surface with a clean, alcohol-soaked rag. Wipe with a dry rag. Repeat until drum is spotless.

INSPECT BRAKE DRUM

Inspect the brake drum for scoring, cracking, heat checking, bell-mouth wear, and barrel-shape wear. Refer to Fig. 31-62.

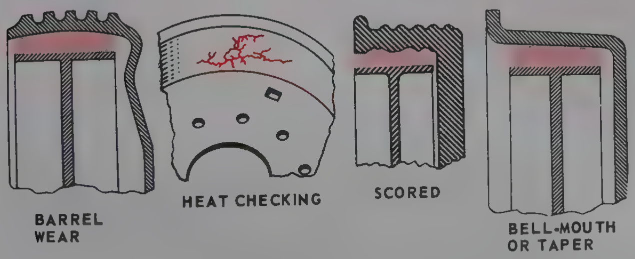


Fig. 31-62. Brake drum wear patterns. (Wagner)

Scoring, bell-mouth, and barrel wear may be removed by turning if not too deep. DESTROY ANY DRUM THAT IS ACTUALLY CRACKED. NEVER TRY TO WELD A CRACKED DRUM.

Heat checking can also be minimized and often removed by turning the drum.

Use a brake drum micrometer to check for out-of-roundness. Measure in 45 deg. increments around the drum.

Although some specifications call for less runout, any drum measuring more than .010 in. (0.254 mm) out-of-round or showing more than .005 in. (0.127 mm) taper should be trued by turning or grinding. Drums that measure over .060 in. (1.524 mm) above standard should be DESTROYED. This does not apply to truck drums. Some car drums cannot exceed .030 in. (0.762 mm). Check manufacturer's specifications.

If the drum appears serviceable without turning, polish with fine emery cloth. This will remove the glassy surface that could cause poor brake action with the new shoes. See Fig. 31-63.

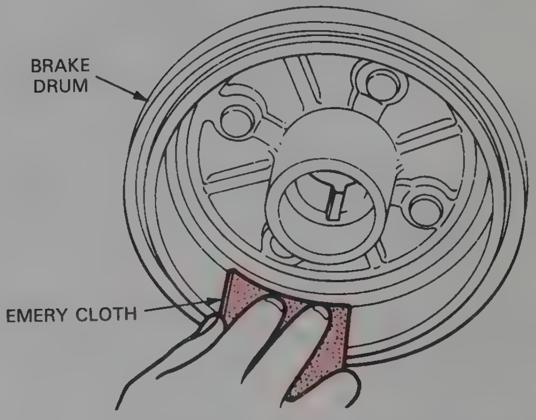


Fig. 31-63. Using emery cloth to clean and deglaze brake drum lining contact surface. Clean thoroughly when finished. (Mazda)

Fig. 31-64 shows a drum micrometer being used to check for drum out-of-roundness.

USE THICKER LINING WITH OVERSIZE DRUMS

Always compare the drum diameter with the standard size. If the drum has been turned to .030 in. (0.762 mm) or more oversize, oversize (thicker) lining or shim stock must be used to produce proper lining-to-drum contact without excessive grinding.

TURN DRUMS IN PAIRS

Although brake drums can be slightly different in diameter between front and rear, the front drums must both be within .010 in. (0.254 mm) of the same diameter and preferably, the same diameter. Both rear drums must also be the same diameter. WHEN A DRUM ON ONE SIDE NEEDS TURNING, TURN THE ONE ON THE OTHER SIDE TO THE SAME DIAMETER.

REMOVE AS LITTLE METAL AS POSSIBLE

Because the drum is made thinner by turning, remove only enough metal to true the drum. Never increase the standard drum diameter by more than .060 in. (1.524 mm). The removal of too much drum metal can cause overheating, checking, and failure.

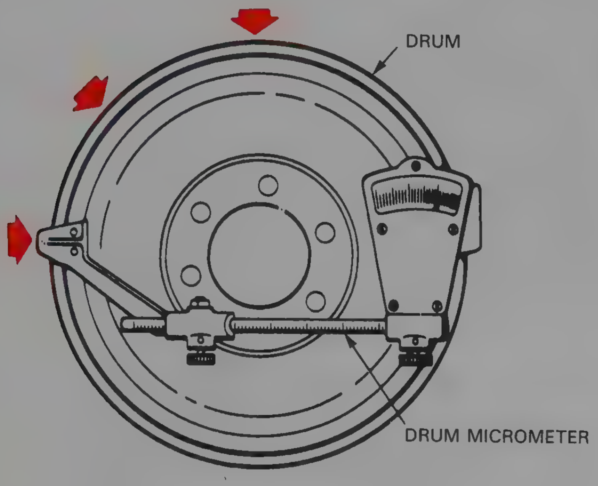


Fig. 31-64. A drum micrometer is used to check brake drum for out-of-roundness. Check in several spots. (Wagner)

USING A DRUM LATHE OR GRINDER

Drums may be trued by turning (using a cutter bit) or by grinding (passing a high speed grinding wheel across revolving drum).

Many shops use only turning. Some turn and then dress very lightly with the grinder. Others use only the grinder.

The turned finish, if tool is sharp, cut light, and feed slow, will be satisfactory. It can be slightly more resistant to squeal and chatter than the ground surface. Fig. 31-65 illustrates a brake drum lathe. Note tool bit.

Fig. 31-66 shows a drum grinder in action. The drum must be accurately mounted. The cut must be light and the feed slow to produce a satisfactory finish. Be sure to place a damper on the drum to prevent chatter marks. Follow the tool manufacturer's directions.

Following truing, clean the drum braking surface with a scrub brush and hot, soapy water. Rinse with hot water and dry immediately. Wipe off with a clean, alcohol-soaked rag.

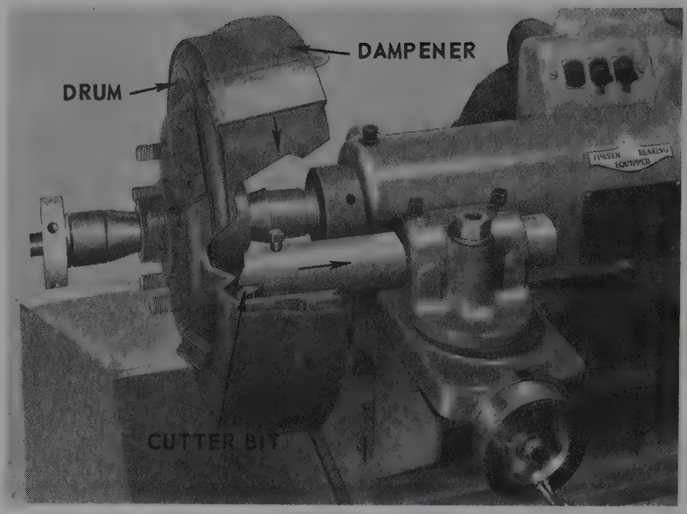


Fig. 31-65. Turning a drum in a brake lathe. Drum is cut away to show cutter bit. (Bear)

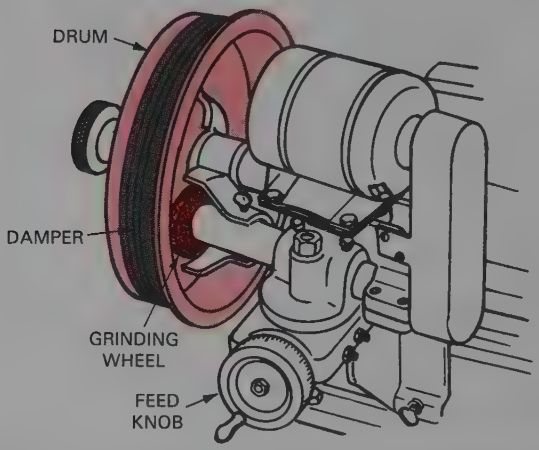


Fig. 31-66. Grinding a brake drum with special grinder. Wear safety goggles! (FMC)

CLEAN NEW DRUMS

New drums are usually given a protective coating to guard against rust. Remove the coating and clean the braking surface with alcohol. Some coatings require lacquer thinner for removal.

METALLIC LINING

To use metallic lining, the drum must be honed to a 20 micro-inch finish. Special heat resistant brake springs must also be used.

Fig. 31-67 illustrates one of the bonded metallic shoe pads. Each pad consists of a top friction facing with a bottom section of bonding material. If shoe pads are worn, the facing area will be greatly reduced. Replace these shoes when either end of the pad measures under 3/32 in. (2.38 mm). See Fig. 31-67.

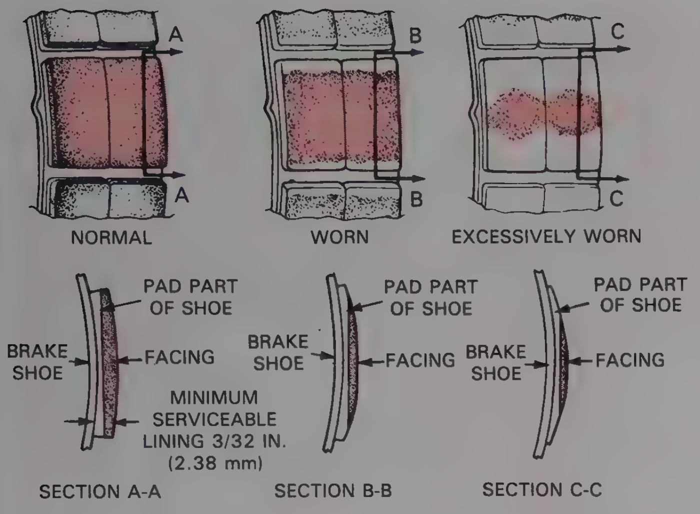

A
A
B
B
C
C
NORMAL
WORN
EXCESSIVELY WORN
PAD PART OF SHOE
BRAKE SHOE
FACING
MINIMUM SERVICEABLE LINING 3/32 IN. (2.38 mm)
PAD PART OF SHOE
BRAKE SHOE
FACING
PAD PART OF SHOE
BRAKE SHOE
FACING
SECTION A-A
SECTION B-B
SECTION C-C

Fig. 31-67. Metallic brake lining wear patterns. (Chevrolet)

PARKING BRAKE ADJUSTMENT — DRIVE SHAFT TYPE

To adjust the external type drive shaft brake, Fig. 31-68, release hand brake all the way. Disconnect brake cable. Adjust cam arm so that cam lies flat (fully released).

Remove anchor cap screw lock wire and adjust cap screw until .025 in. (0.635 mm) clearance exists between lining and drum at the anchor location. Secure this clearance between lining and drum at the lower half of the band by turning the lower adjusting nut.

Recheck for proper clearance. Replace anchor cap screw locking wire. Do not draw up tightly. Tighten guide bolt locknut.

Cable length should be adjusted to align holes in cable yoke and cam arm. Install clevis pin. Use a new cotter pin. Replace pull back spring. See Fig. 31-68.

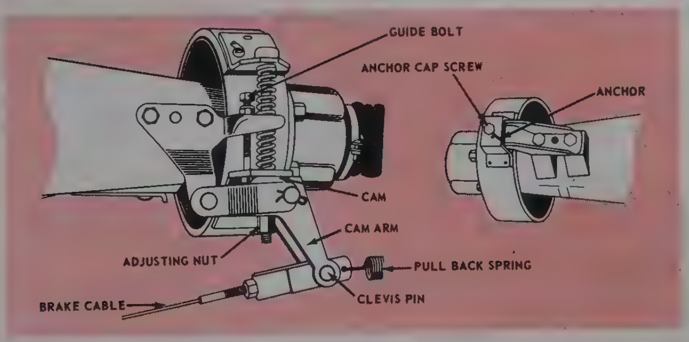

GUIDE BOLT
ANCHOR CAP SCREW
ANCHOR
CAM
CAM ARM
ADJUSTING NUT
PULL BACK SPRING
BRAKE CABLE
CLEVIS PIN

Fig. 31-68. External drive shaft parking brake. (Bear)

ADJUSTING INTERNAL TYPE DRIVE SHAFT PARKING BRAKE

To adjust the internal drive shaft parking brake, Fig. 31-69, place the transmission in neutral and fully release the parking brake lever.

Disconnect the front end of the propeller shaft so that the drum will revolve freely. Remove adjusting cover located at the bottom of the backing plate. Loosen the clamp bolt and back off cable adjusting nut.

Disconnect cable and check for freedom of operation. Lubricate cable or replace as needed. Install cable.

Expand shoes outward until a light drag is felt. Back off one or more notches to secure .010 in. (0.254 mm) lining-to-drum clearance. Raised lugs on adjustment nut should be seated in adjusting sleeve grooves. Turn cable adjusting nut against cable clamp until this clearance exists between the end of the operating lever and the brake shoe rim.

Tighten cable clamp bolt. Replace adjusting cover. Attach propeller shaft. Test brake by applying parking brake. Brake should be securely applied when lever has traveled no more than four to six notches.

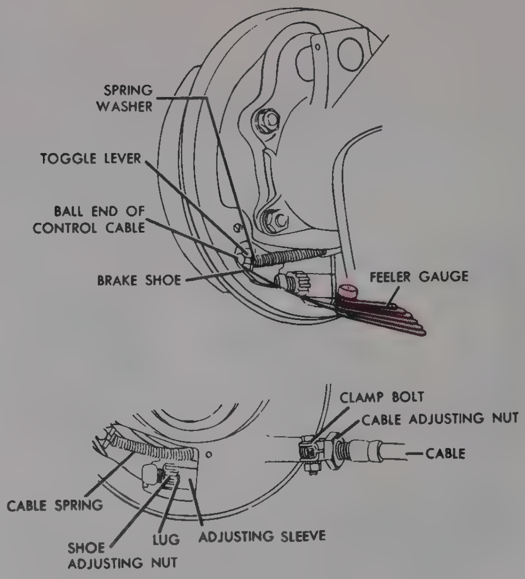

SPRING WASHER
TOGGLE LEVER
BALL END OF CONTROL CABLE
BRAKE SHOE
FEELER GAUGE
CLAMP BOLT
CABLE ADJUSTING NUT
CABLE
CABLE SPRING
LUG
ADJUSTING SLEEVE
SHOE ADJUSTING NUT

Fig. 31-69. One type of internal drive shaft parking brake. (World-Bestos)

NEVER TRY TO ADJUST THE INTERNAL PARKING BRAKE BY ADJUSTING THE CABLE ONLY. THE SHOES MUST BE ADJUSTED FIRST — THEN THE CABLE. See Fig. 31-69.

PARKING BRAKE ADJUSTMENT — DISC BRAKE TYPE

Vehicles with disc brakes in the rear require a somewhat different procedure for adjustment of the parking brake mechanism. There are two basic types; the internal expanding shoe and drum type and a screw actuated unit type which is an integral part of the caliper. See Figs. 31-70 and 31-71.

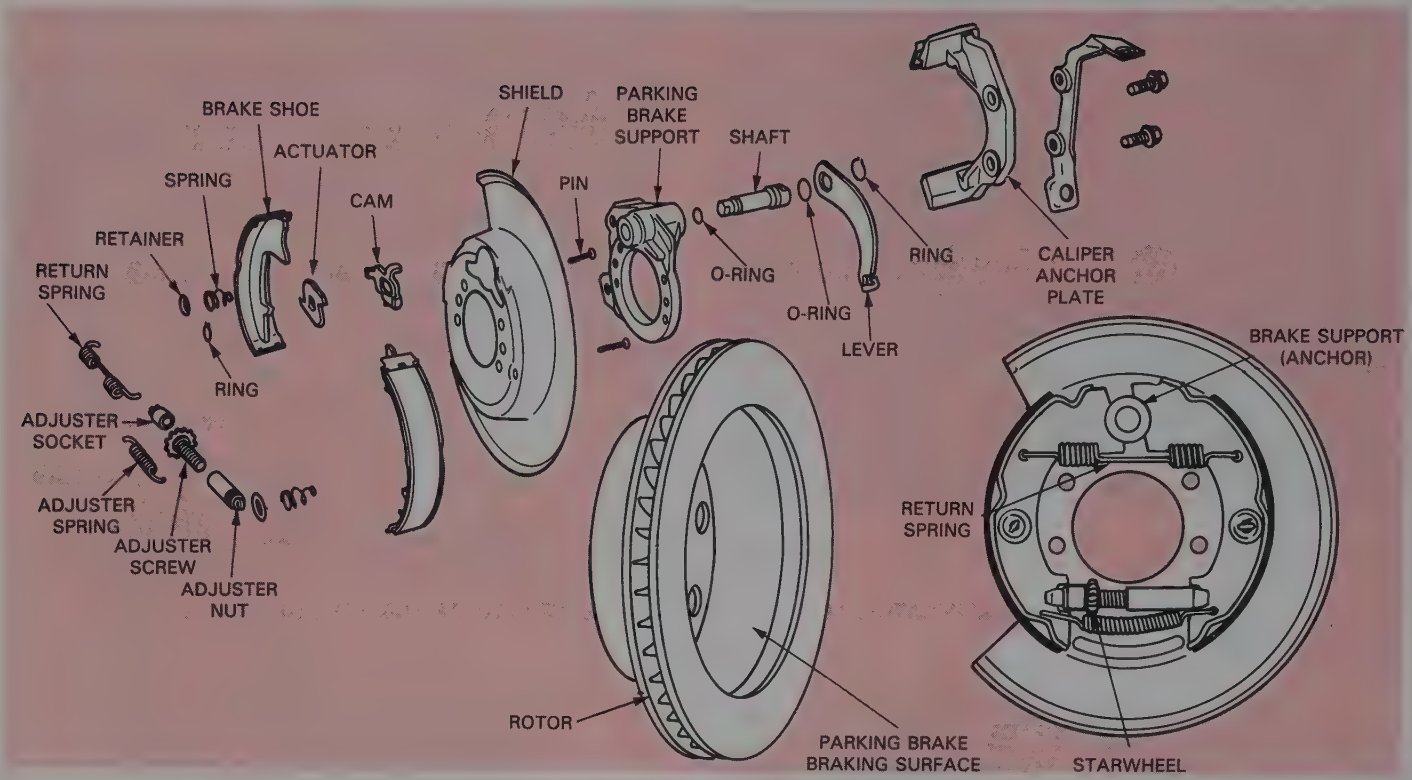

BRAKE SHOE
ACTUATOR
SPRING
CAM
RETAINER
RETURN SPRING
RING
ADJUSTER SOCKET
ADJUSTER SPRING
ADJUSTER SCREW
ADJUSTER NUT
SHIELD
PARKING BRAKE SUPPORT
SHAFT
PIN
O-RING
O-RING
LEVER
RING
CALIPER ANCHOR PLATE
BRAKE SUPPORT (ANCHOR)
RETURN SPRING
ROTOR
PARKING BRAKE BRAKING SURFACE
STARWHEEL

Fig. 31-70. Rotor-drum type parking brake assembly. Study parts, names, and relationships. (FMC)

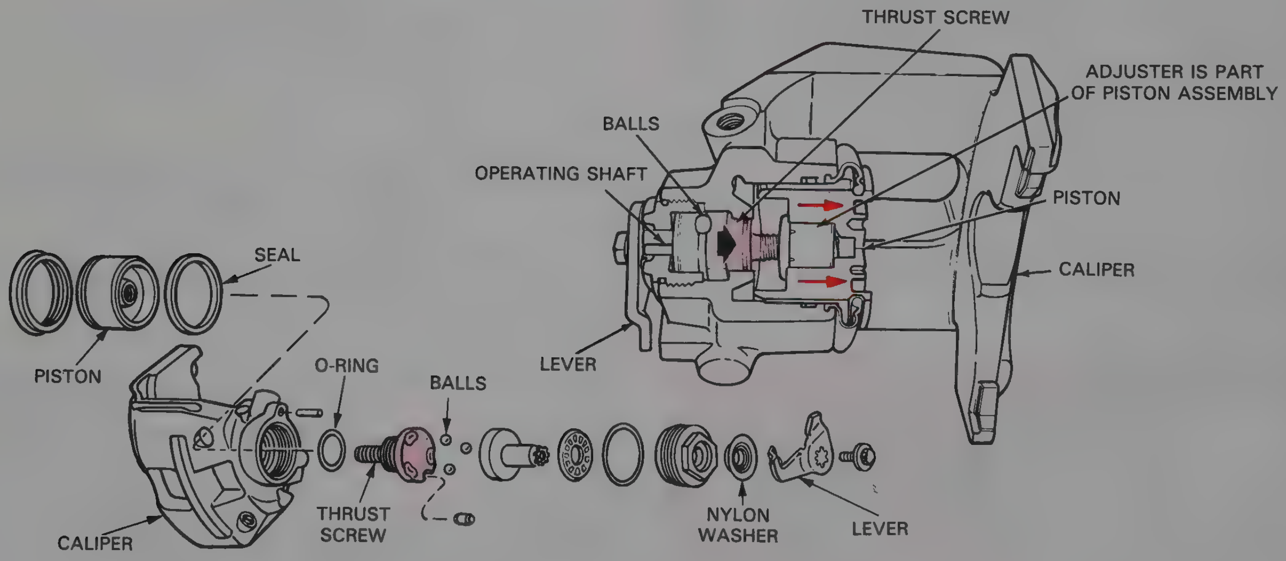

THRUST SCREW
ADJUSTER IS PART OF PISTON ASSEMBLY
BALLS
OPERATING SHAFT
PISTON
CALIPER
LEVER
SEAL
PISTON
O-RING
BALLS
CALIPER
THRUST SCREW
NYLON WASHER
LEVER

Fig. 31-71. Cutaway and exploded view of a screw actuated disc brake, parking brake assembly. As thrust screw is turned by lever, piston firmly clamps rotor between pads. (FMC)

To adjust the disc (drum) type, Fig. 31-72, rotate the star wheel by placing an adjusting tool through an opening generally located in the face of the rotor-drum.

If parking brake shoes require replacement, disconnect caliper, back off star wheel (if necessary). Remove rotor-drum unit. The shoes are serviced in the same manner as the servo type service brake.

To compensate for new shoes or cable wear, engage the parking brake pedal or hand lever one notch. Adjust cable for slack at the equalizer.

For adjustment of the screw type, all that is generally necessary is adjustment of the cable. This too, is performed at the equalizer. Check all parts for freedom of movement. Follow maker's service procedures.

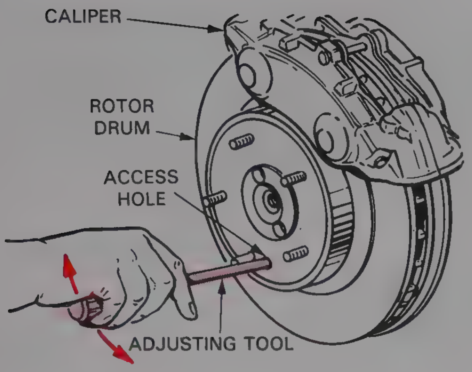


Fig. 31-72. Adjusting rotor-drum parking brake. Rotating internal star wheel provides adjustment of shoe-to-drum clearance. (FMC)

SHIFT POINTS WILL BE AFFECTED BY IMPROPER PARKING BRAKE ADJUSTMENT

The internal type parking brake must be carefully adjusted. If set too close, friction between the lining and drum will alter the shift points in an automatic transmission.

ADJUSTING PARKING BRAKE — REAR WHEEL TYPE

Apply the parking brake around 3 notches (about 1 3/4 in. or 44.5 mm travel). Adjust the equalizer nut until a slight drag is noticeable at the rear wheels. Refer to Fig. 31-73.

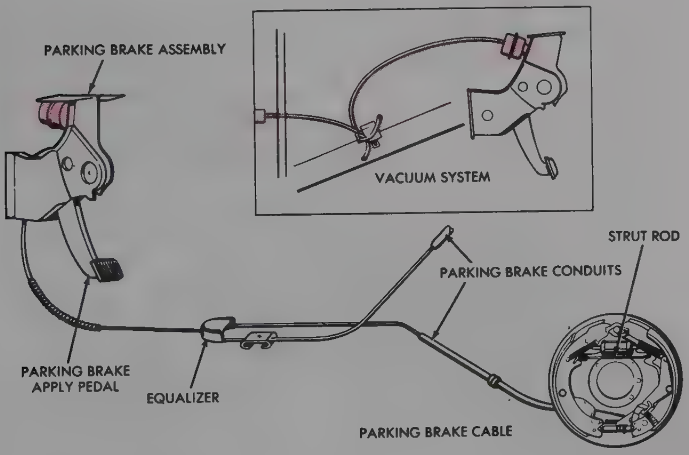


Fig. 31-73. Typical rear wheel parking brake arrangement. Note automatic vacuum release. (Cadillac)

Release the brake. Wheels should turn FREELY. Parking brake cables must operate freely. Lubricate if needed.

NOTE: The parking brake must release fully. If the brake is set too tight, it can cause the automatic adjuster to malfunction. It can also ruin the lining from overheating. The service brakes should be properly adjusted before adjusting the parking brake.

BRAKE LINES AND HOSE

Brake lines must be in excellent condition, free of rust, dents, kinks, or abraded areas. They must be supported to prevent vibration.

Hoses must be free of cracking, kinking, swelling, and cuts. Hoses must not contact any moving parts.

When replacing brake lines, use only double-wrapped, coated steel tubing. Double-lap flare tubing ends. See chapter on tubing and hose for complete instructions on flaring, cutting, and bending. Fig. 31-74 illustrates the formation of a double-lap flare. Fig. 31-75 pictures an I.S.O. (International Standards Organization) type flare. These are NOT interchangeable.

NEVER USE COPPER TUBING FOR BRAKE LINES.

STOPLIGHT SWITCH

Stoplight switches are either of the hydraulic type (operated by pressure in brake system) or mechanical

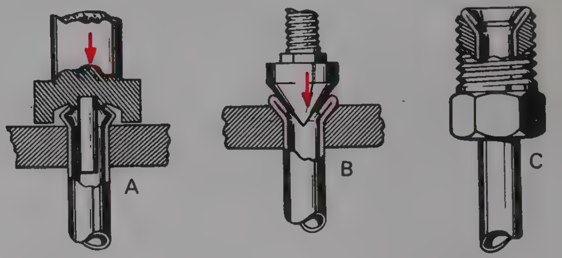


Fig. 31-74. Steps involved in forming a double-lap flare. A—Forming single lap. B—Forming double lap. C—Finished double-lap flare with fitting. (Bendix)

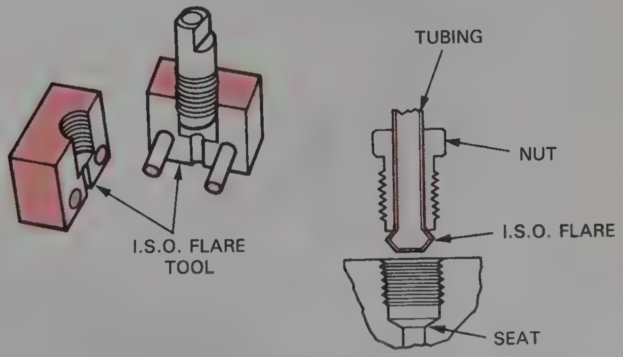


Fig. 31-75. Cutaway view of an I.S.O. (International Standards Organization) flare and seat. Note the special tool required to form this flare. Follow the tool manufacturer's instructions. DO NOT use this flare with a single-lap or double-lap flare arrangement. (Bendix)

type (operated by brake pedal).

Adjust mechanical switch as specified so that only a small amount of brake pedal movement is required to operate the switch. Fig. 31-76 shows the adjustment distance for one specific installation.

Make certain the stoplight switch does not prevent the brake pedal from returning to the fully released position. Some units adjust automatically.

BRAKE FLUID

Use only top-quality, DOT (Department of Transportation) approved brake fluid. Regular or silicone fluid can be utilized. Disc brake systems require a fluid that is highly resistant to heat. NEVER reuse brake fluid or mix regular and silicone fluids together. Keep fluid in clean, tightly sealed, well-marked containers. Protect from contamination with dust, water, and oils.

BLEEDING THE BRAKES

Bleeding the brakes means removing air from brake system. Air can enter in a number of ways: a low fluid level in master cylinder; part of the system disconnected; leaky wheel or master cylinder cups; overheating of brakes with resultant "gassing" of fluid. Air in the system causes a springy or spongy "feel" when braking.

Bleeding consists of pumping fresh fluid throughout the system. This forces air out through the wheel cylinder or caliper bleeder valves. Brakes can be bled by manual or pressure means.

MANUAL BLEEDING

Clean all wheel cylinder or caliper bleeder screws. Remove cap or plug from bleeder screw, if used. Attach a bleeder hose to the bleeder screw farthest from the master cylinder. Place the free end in a clear glass jar partially filled with brake fluid. Look at Fig. 31-77.

Clean master cylinder reservoir cap and surrounding area. Fill reservoir almost to top.

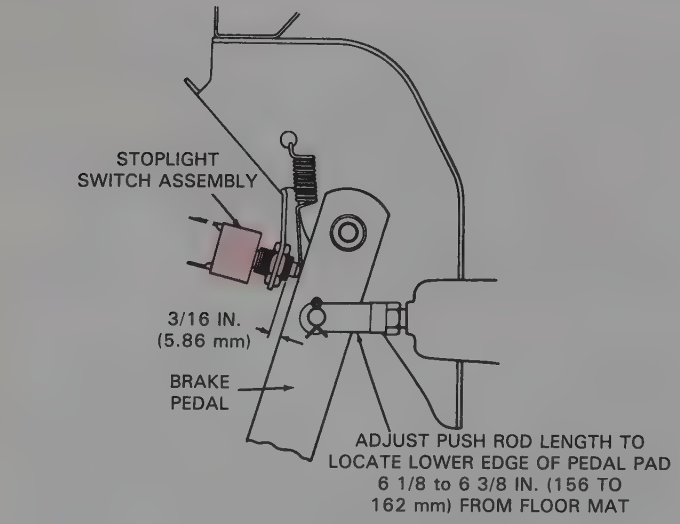

STOPLIGHT SWITCH ASSEMBLY
3/16 IN. (5.86 mm)
BRAKE PEDAL
ADJUST PUSH ROD LENGTH TO LOCATE LOWER EDGE OF PEDAL PAD 6 1/8 to 6 3/8 IN. (156 TO 162 mm) FROM FLOOR MAT

Fig. 31-76. One stoplight switch arrangement. (Pontiac)

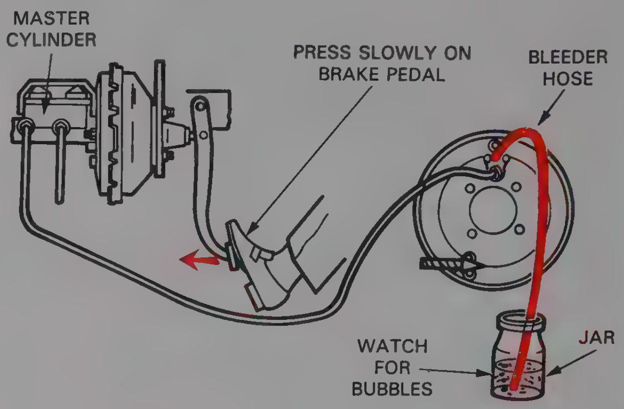


Fig. 31-77. Manual (by foot) bleeding a rear wheel cylinder. Be sure to place bleeder hose in brake fluid jar. (Niehoff)

Open the bleeder screw 3/4 turn. FREE END OF HOSE MUST BE SUBMERGED IN THE JAR OF FLUID. Press the brake pedal slowly to the floor. This will force air and fluid from wheel cylinder. RELEASE PEDAL SLOWLY. Repeat this process (keep reservoir filled at all times) until fresh brake fluid, with no air bubbles, flows into the jar. See Fig. 31-78.

Tighten bleeder screw. Remove hose and move setup to wheel on opposite side of car. Bleed remaining cylinders or calipers in same manner.

If desired, instead of letting up the brake pedal slowly, the bleeder screw may be closed after the pedal is depressed but before releasing. The pedal may then be released swiftly. Press pedal down and reopen bleeder. When pedal reaches the floor, shut off again before releasing brake. Repeat until clear fluid, with no air, enters jar.

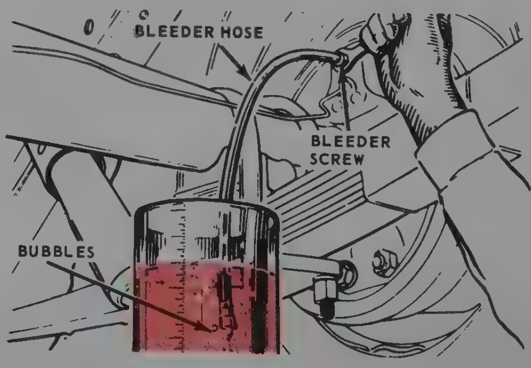


Fig. 31-78. Bleed cylinder until clear fluid, with NO aid bubbles, flows from hose. Note bubbles still being forced from this system.

Make certain all bleeder screws are shut off firmly. When bleeding disc brakes, rap caliper with a plastic hammer to dislodge air bubbles clinging to caliper wall.

DISCARD THE BRAKE FLUID IN THE JAR. NEVER UNDER ANY CIRCUMSTANCES MUST IT BE REUSED IN A BRAKE SYSTEM.

PRESSURE BLEEDING

Pressure bleeding is faster than manual bleeding and requires only one person. Manual bleeding requires one person to operate the brake and another to watch the wheel area.

A pressure tank, partially filled with brake fluid, is attached to the master cylinder reservoir. Fig. 31-79 illustrates a typical pressure bleeding hookup.

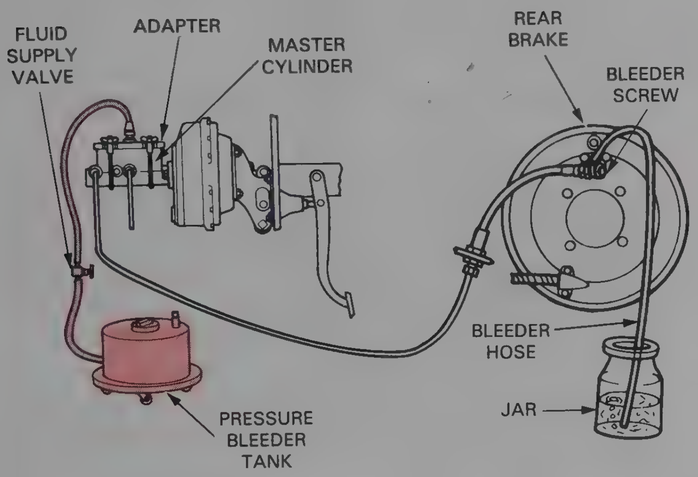


Fig. 31-79. Bleeding a rear brake with a pressure bleeder tank and adapter. This method is generally recommended over manual bleeding. (Niehoff)

PRESSURE BLEEDING TANK

Some pressure tanks separate the fluid from the compressed air with a diaphragm. In tanks without a diaphragm, it is mandatory that only clean, dry, oil-free, compressed air be used.

Fill the tank to the specified level and charge to 20-30 psi (138-207 kPa) with air hose. Avoid shaking the tank as this tends to form air bubbles. Keep tank at least 1/3 full.

Bleed the tank as required. Then, with an adapter, attach to filled master cylinder reservoir. Adapter and master cylinder must be clean.

Turn on the tank hose valve to admit fluid pressure to the master cylinder. Attach bleeder hose. Open bleeder and allow fluid to flow from cylinder until clean and free of air bubbles. Close bleeder securely. Repeat on remaining wheels.

Shut off pressure tank and remove. Siphon off enough fluid to lower the master cylinder fluid level to 3/8 in. (9.53 mm) from the top.

BLEEDING SERIES AND PARALLEL CONNECTED WHEEL CYLINDERS

In cases where two wheel cylinders are used at each wheel, determine if they are connected in series, B, or in parallel, A, Fig. 31-80.

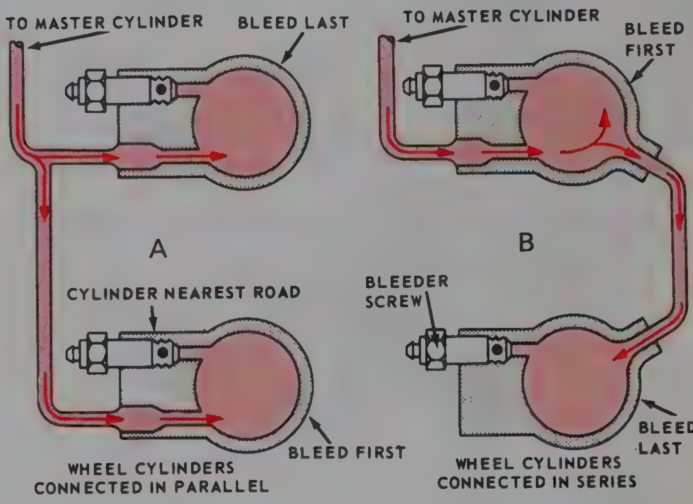


Fig. 31-80. Connected wheel cylinders. A—Parallel. B—Series. (Bear)

In cases where series connected cylinders both have bleeder screws, bleed the cylinder connected to the lead-in line (cylinder closest to master cylinder) first. On parallel connected setups, bleed the lowest (closest to road) cylinder first.

It may be necessary to bleed both several times to remove all air.

BLEEDING POWER BRAKES

Bleed power brakes as already described. In cases where the power assist unit or master cylinder is equipped with a bleeder screw, bleed at these points first. Close bleeder before releasing pedal when bleeding power units. Refer to Fig. 31-81.

BLEEDING SPLIT SYSTEMS (USING TANDEM MASTER CYLINDER)

If the master cylinder has two caps but a common reservoir, attach pressure bleeder tank to one hole. Insert a blind (no vent hole) cap in the other. If separate reservoirs are used, attach to one and bleed that side. Then attach to other.

When bleeding tandem master cylinders, bleed the wheels served by primary piston (not floating piston) first. See Fig. 31-82.

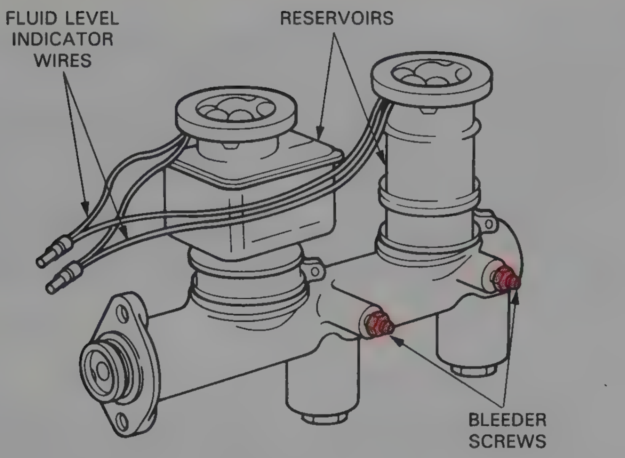


Fig. 31-81. Master cylinder bleeder screws. Note separate reservoirs and use of fluid level indicators and wires. (Niehoff)

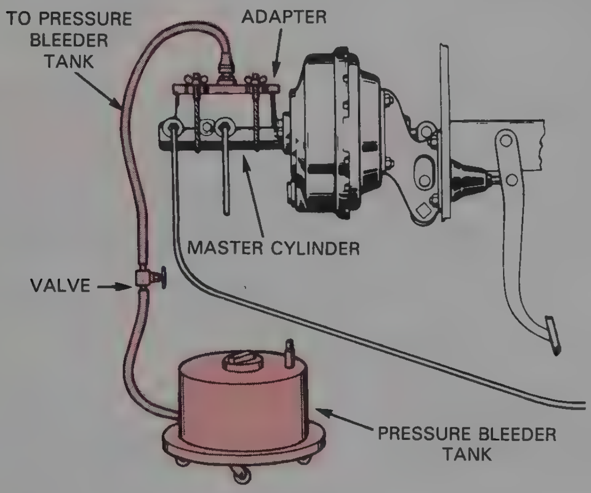


Fig. 31-82. Attaching pressure bleeder adapter to master cylinder. (Bendix)

SURGE BLEEDING CAN HELP

In cases where it is difficult to remove the air from the wheel cylinder, try surge bleeding. Attach pressure bleeder and admit pressure to master cylinder. Open a bleeder screw and have a helper depress the brake pedal with a fast movement. Release pedal slowly. Wait a few seconds and repeat. Continue until air is expelled. On the last downstroke of the brake pedal, close the bleeder screw quickly.

BLEEDING DISC BRAKE SYSTEMS

When front disc brakes are used, the metering valve must be blocked open. A spring-like hold-open tool is recommended to prevent valve damage.

Some installations require the removal of the pressure differential warning light switch terminal and plunger to prevent switch damage during bleeding.

BLEEDING ANTI-LOCK BRAKE SYSTEM

Procedures for bleeding anti-lock brake systems vary among manufacturers. ALWAYS consult the vehicle's service manual and follow the recommendations carefully. REMEMBER: The working pressure of some boost systems can reach 2600 psi (1 793 kPa). These systems MUST be pumped down to relieve pressure before the lines can be loosened. Failure to do so can result in injury.

FLUSHING THE SYSTEM

If necessary, the brake system may be flushed with new brake fluid. It can also be flushed with alcohol and rinsed with brake fluid. Alcohol should not be used unless the master cylinder, calipers, and wheel cylinders are to be reconditioned. Flushing should always be done prior to repairs.

BREAKING IN A NEW SET OF BRAKE LININGS

Following the installation of new brake linings, it is important that they be given the proper break-in.

When road testing following completion of brake job, make eight or ten mild stops from around 25 mph (40.2 km/h). Make the same number of stops from around 45 mph (72.4 km/h) at one mile (1.6 km) intervals. Stops must be MILD.

Caution owner to avoid severe use of the brakes for several hundred miles. This will seat the linings properly and lengthen service life.

DISC BRAKES

Disc brakes utilize a heavy disc (often called a rotor) instead of the conventional brake drum. The disc may be solid or have cooling slots in the center.

The disc is bolted to the wheel hub. A brake caliper, bolted to the spindle, surrounds the disc. When the brake is applied, hydraulic pressure forces friction pads against the revolving disc. This will stop the disc.

Disc brakes are highly resistant to fade (loss of friction from overheating). A typical disc brake assembly is pictured in Figs. 31-83 and 31-84.

CALIPER CONSTRUCTION

A caliper utilizing two hydraulic pistons on each side is illustrated in Fig. 31-85. This particular caliper may have the two halves separated for repair. New seal rings must be used when bolting the halves back together. SOME CALIPERS MUST NOT HAVE THE HALVES SEPARATED.

The friction pads are self-adjusting and run with very little clearance between the lining and disc. One design

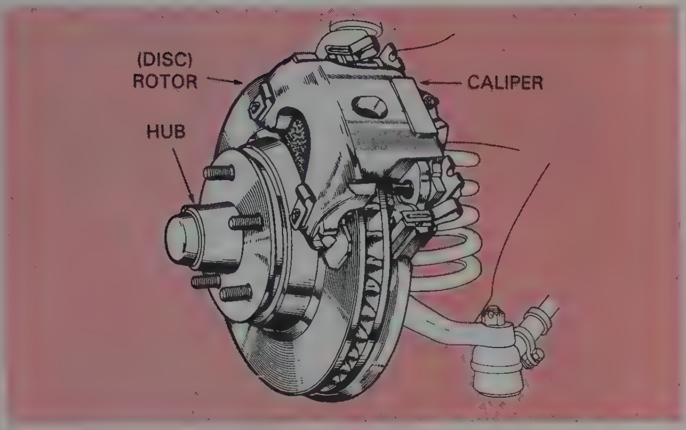

(DISC) ROTOR
CALIPER
HUB

Fig. 31-83. Typical disc brake assembly. (Bendix)

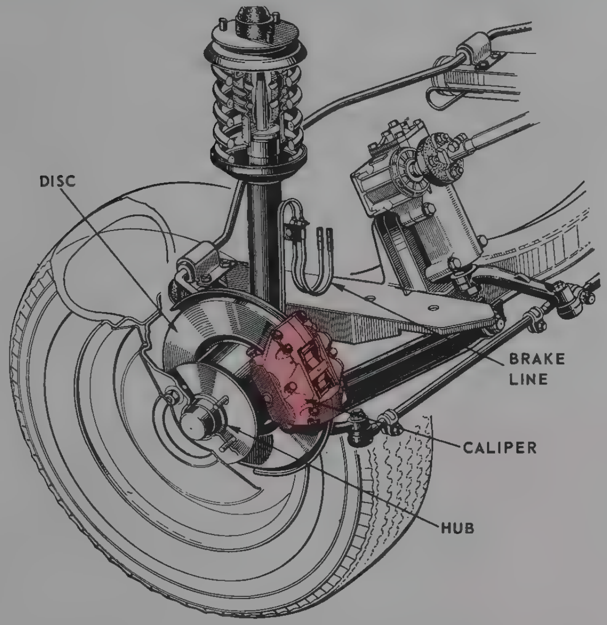

DISC
BRAKE LINE
CALIPER
HUB

Fig. 31-84. Typical front wheel disc brake setup. (BMW)

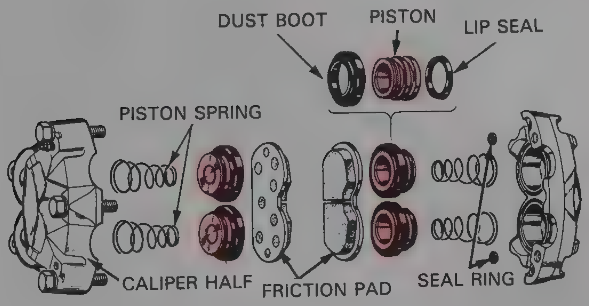

DUST BOOT
PISTON
LIP SEAL
PISTON SPRING
CALIPER HALF
FRICTION PAD
SEAL RING

Fig. 31-85. Exploded view of a disc brake caliper utilizing two pistons in each half. (American Motors)

actually allows the pads to rub the disc very lightly at all times.

The technique used to maintain pad clearance in the caliper shown in Fig. 31-86 is simple and effective.

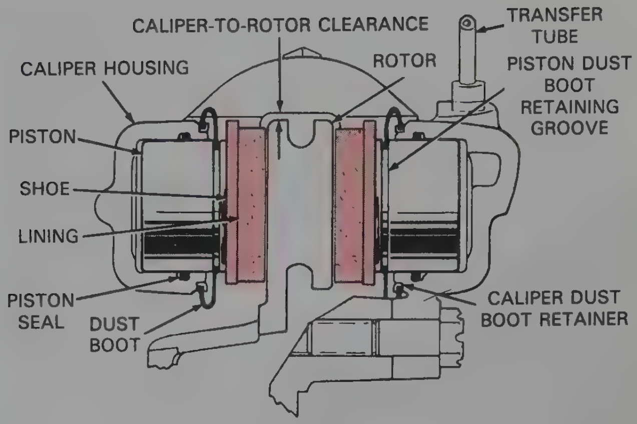

CALIPER-TO-ROTOR CLEARANCE
TRANSFER TUBE
CALIPER HOUSING
ROTOR
PISTON DUST BOOT RETAINING GROOVE
PISTON
SHOE
LINING
PISTON SEAL
DUST BOOT
CALIPER DUST BOOT RETAINER

Fig. 31-86. One type of caliper pad and piston design. (Lincoln)

When the piston is forced outward to apply the disc, the piston seal stretches slightly to the side, A, Fig. 31-87. When the pedal is released, the seal straightens up and draws the piston back far enough for the pad to clear the disc, B. In addition to the withdrawal action of the seal, any slight runout in the disc also helps to push the pad away.

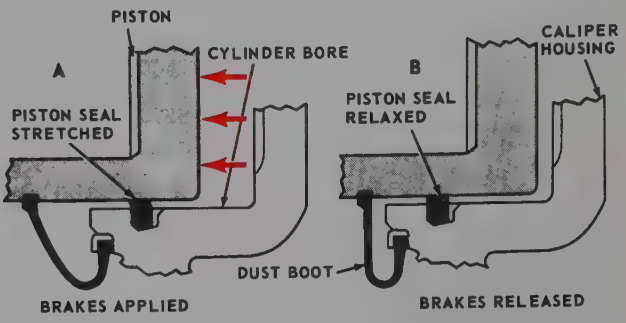

PISTON
CYLINDER BORE
A
PISTON SEAL STRETCHED
B
CALIPER HOUSING
PISTON SEAL RELAXED
DUST BOOT
BRAKES APPLIED
BRAKES RELEASED

Fig. 31-87. Seal action maintains proper pad-to-disc clearance. A—Brakes applied, seal forced sideways. B—Brakes released, seal pulls piston back.

FIXED AND FLOATING CALIPERS

Some caliper assemblies are held rigidly in place (fixed) and require the use of at least one piston on each side to force the pads against the disc. Fig. 31-85 illustrates a four piston caliper.

The floating (free to slide sideways) caliper often only uses one piston. As the piston is forced out, it first shoves the brake pad it contacts against the disc. When all movement in this direction is taken up, the caliper itself moves away from the piston. This draws the other pad (installed in outboard side of caliper) against the disc or rotor. Further piston travel merely applies pressure to both pads.

Actual movement is very small as the pads barely clear the disc after the brakes have been released. Fig.

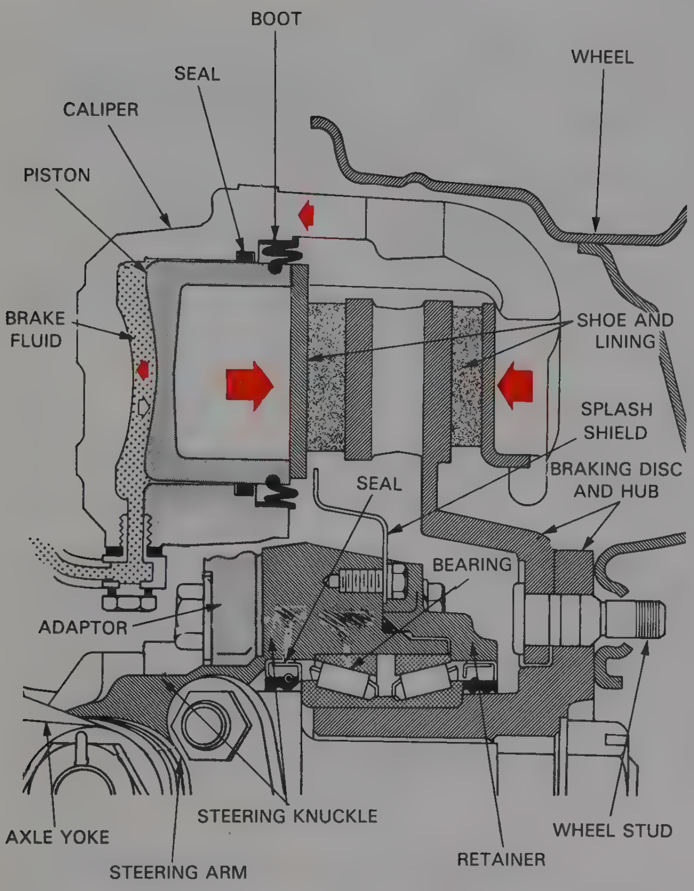

BOOT
SEAL
CALIPER
PISTON
WHEEL
BRAKE FLUID
SHOE AND LINING
SPLASH SHIELD
SEAL
BRAKING DISC AND HUB
BEARING
ADAPTOR
STEERING KNUCKLE
WHEEL STUD
AXLE YOKE
RETAINER
STEERING ARM

Fig. 31-88. Cross section of a single piston, floating caliper disc brake as used on one type of front wheel drive vehicle. (Dodge)

31-88 shows the various parts of the single piston, floating caliper assembly.

Regardless of the wear determining device, pads should be changed when worn to within 1/8 in. (3.18 mm) of pad base. Refer to Fig. 31-89.

CHANGING FRICTION PADS

Before forcing the piston back, siphon off brake fluid from the master cylinder disc brake reservoir (until it is about one third full), to make room for that displaced when the piston is forced inward. Failure to do this will result in flooding the master cylinder. See Fig. 31-90.

If necessary, remove the caliper. Do not allow the caliper to hang from the brake hose (or sensor wire). Use a C-clamp to force the pistons back into the bore. This will free the pads from the disc, Fig. 31-91.

When the pads are moved away the full distance (this bottoms pistons in their bores), the pads may be withdrawn. Some pads are positioned with pins. The pads in Fig. 31-92 may be pulled out with pliers. They are free when the caliper splash shield is removed.

When the pads are removed, check the pistons and boots for leakage, corrosion, and gumming. If necessary, disassemble and clean (See Caliper Repair). Check disc for excessive scoring and oil or grease.

Insert new pads. Lubricate (as recommended) any sliding metal surfaces with special grease (such as molydisulfide). Install splash shield or any other pad

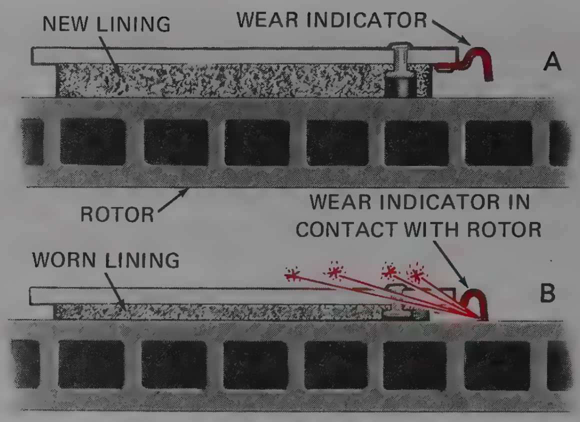

NEW LINING
WEAR INDICATOR
A
ROTOR
WEAR INDICATOR IN CONTACT WITH ROTOR
WORN LINING
B

Fig. 31-89. Warning wear indicator tab action. A—New pad. Indicator does not touch disc. B—Pad worn. Indicator strikes disc and alerts driver of worn pad. (Oldsmobile)

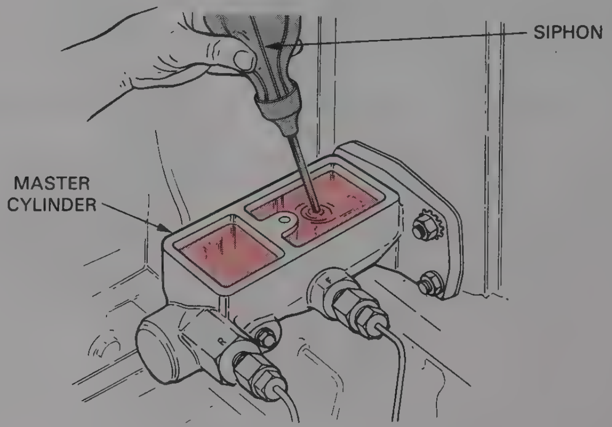

SIPHON
MASTER CYLINDER

Fig. 31-90. Removing brake fluid from reservoir with a siphon. Do not reuse old fluid. (FMC)

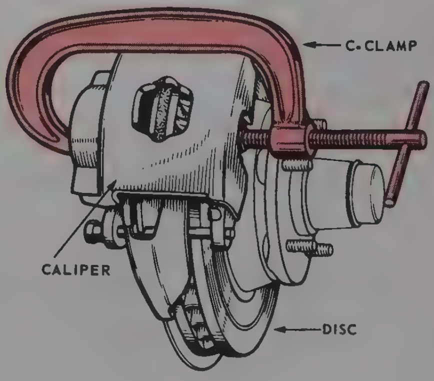

C-CLAMP
CALIPER
DISC

Fig. 31-91. Using clamp to force brake piston back into bore to free brake pads. (Bendix)

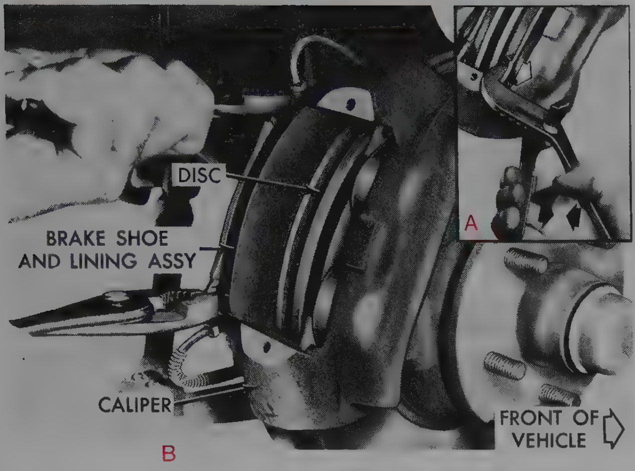

DISC
BRAKE SHOE AND LINING ASSY
A
CALIPER
FRONT OF VEHICLE
B

Fig. 31-92. Pulling friction pads from caliper. A—Pushing piston back. B—Removing pad. (Plymouth)

holding device. Always use appropriate fasteners.

Pump brake pedal to force pads out against disc. Bring master cylinder to correct level. DO NOT ATTEMPT TO DRIVE THE CAR UNTIL A FULL PEDAL IS OBTAINED BY PUMPING THE PEDAL UNTIL THE PADS ARE AGAINST THE DISC. THE BRAKES WILL NOT FUNCTION ON THE FIRST APPLICATION OF THE PEDAL IF THIS IS NOT DONE.

CALIPER REMOVAL AND OVERHAUL

When the caliper is removed, check carefully for any aligning shims. Tag as to proper location.

If the caliper halves may be separated, Fig. 31-85, do so. Then, continue disassembly. See detail A in Fig. 31-93. Remove the piston dust boots (or boot on single piston caliper). Use care (a fiber or plastic pry stick helps) to avoid scratching either the piston or cylinder wall, as in detail B.

Remove the pistons. The careful use of an air hose, as shown in detail C in Fig. 31-93, makes removal easy on some calipers. DO NOT remove phenolic (plastic) caliper pistons with air pressure. They require more force to move in their bore than the cast iron type. They can come out with enough force to damage the piston. Remove these with system hydraulic pressure, before brake lines are disconnected from the calipers.

Pad with cloth to avoid piston damage. KEEP FINGERS CLEAR as piston can come out VERY FAST! Turn unit away from face and body. Keep other personnel away and cover whole assembly with heavy shield cloth.

Remove cylinder seal. Use nonmetallic pry tool. When the caliper assembly is stripped, as in detail A, Fig. 31-93, clean all parts in alcohol and blow dry. Make certain air source is OIL FREE. If in doubt, blow dry and give parts a final rinse in CLEAN alcohol and

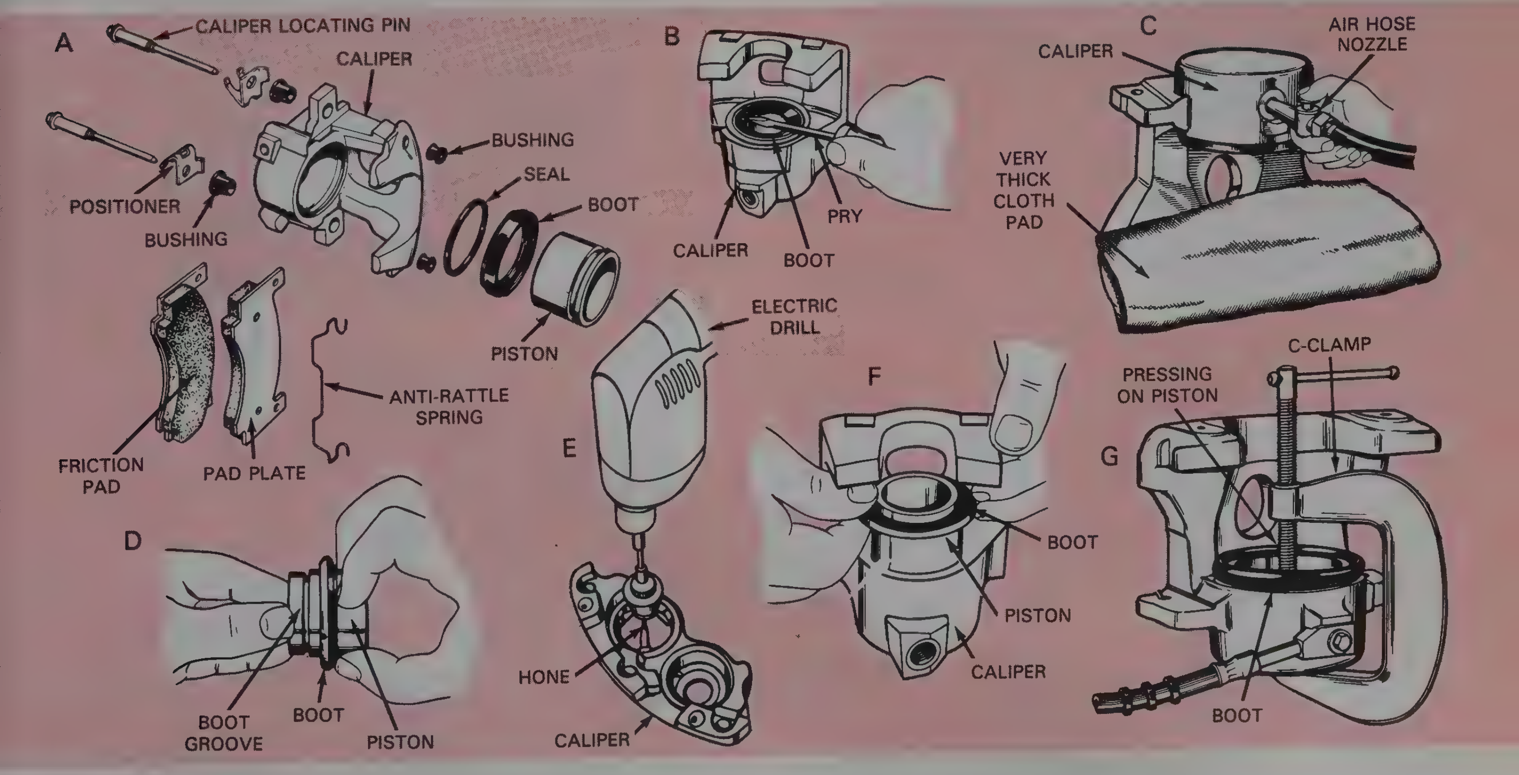

A
CALIPER LOCATING PIN
CALIPER
BUSHING
SEAL
BOOT
POSITIONER
BUSHING
PISTON
ANTI-RATTLE SPRING
FRICTION PAD
PAD PLATE
B
PRY
CALIPER
BOOT
C
CALIPER
AIR HOSE NOZZLE
VERY THICK CLOTH PAD
D
BOOT GROOVE
BOOT
PISTON
E
ELECTRIC DRILL
HONE
CALIPER
F
BOOT
PISTON
CALIPER
G
PRESSING ON PISTON
C-CLAMP
BOOT

Fig. 31-93. Common brake caliper overhaul operations. A—Exploded view of a single piston floating caliper. B—Removing piston boot. C—Careful use of air to remove piston. BE CAREFUL! D—Installing boot on cleaned and lubed piston. E—Honing cylinder bore. F—Inserting piston in clean, lubed bore. G—Forcing piston all the way in with a small C-clamp. (Bendix)

let air dry. BE CAREFUL WITH ALCOHOL – IT IS VERY FLAMMABLE!

Check caliper cylinders carefully for scoring or corrosion. Some assemblies require that a feeler gauge be used between piston and bore to check for proper fit. If in relatively poor condition, discard. If in fair condition, hone as shown in E, Fig. 31-93. Bore size must not be increased by more than around .001 in. (0.025 mm). Use brake fluid on hone. Stones must be FINE.

A cylinder bore in quite good condition can often be cleaned by hand, using crocus cloth.

Following honing (or use of crocus cloth), the entire unit must be thoroughly cleaned in alcohol. Brush out boot and seal grooves with a nonmetallic brush. Thoroughly blow out the grooves and all passageways. Repeat cleaning several times, using CLEAN alcohol.

Coat new piston seal with special lubricant and place into groove in cylinder. Use fingers only. Lube bore. Make sure seal is seated.

Check the condition of the piston(s) and replace if the plating is scored, corroded, or worn. If the caliper contains more than one piston, always replace them in pairs. Check phenolic (plastic) pistons for cracks, gouges, or chips.

Thoroughly clean piston and groove. Coat new boot with special lubricant. Slide boot over piston, as shown in detail D of Fig. 31-93. Some pistons require the use of a special silicone sealer in the dust boot groove. Install it before boot is placed on piston. This is shown in Fig. 31-94. Slide boot into its groove.

Make certain cylinder bore and piston are coated with brake fluid. Place piston in bore and shove inward, as in detail F, Fig. 31-93.

If needed, a C-clamp may be used against piston, as in G, Fig. 31-93. The clamp will hold piston down while the edge of the boot is snapped into place in the caliper boot groove.

When using a C-clamp with plastic pistons, place a smooth piece of metal or wood across the piston. DO NOT place the C-clamp in DIRECT contact with piston or damage to the piston may result. Use a blunt tool. DO NOT puncture boot. If you do, replace boot.

Install brake pads. Some calipers permit installation after caliper is mounted. Secure as needed. Lubricate any recommended surfaces. NEVER GET LUBE ON PAD OR DISC! Install caliper as recommended. Bleed and actuate brakes to make sure caliper pads are in full contact with disc.

The above techniques are common, but variations in calipers might call for a slightly different installation method. Use recommended procedures.

CALIPER ALIGNMENT

Check (if needed) to make certain that caliper is centrally located over disc (not required with floating calipers), Fig. 31-95.

Check that pads are parallel with disc surface. See Fig. 31-96. If alignment error exceeds specifications, check for missing or wrongly placed shims, front end damage, or incorrect installation. Fig. 31-96 shows correct and incorrect caliper-to-disc alignment.

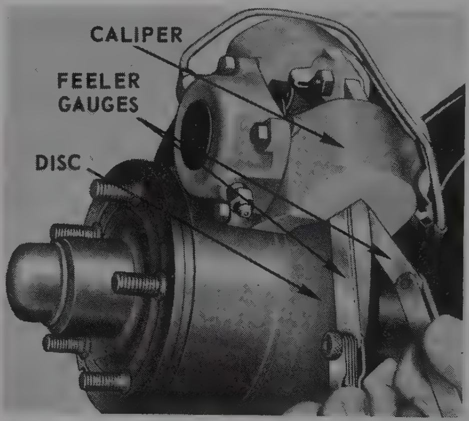


Fig. 31-95. Checking a fixed caliper for proper centering over disc. (Bear)

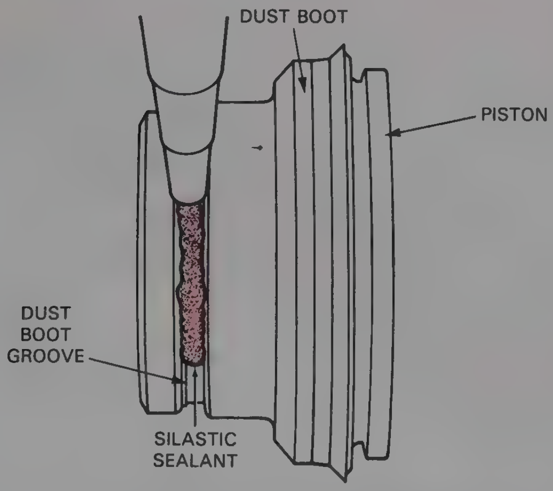


Fig. 31-94. Placing special silicone sealer in dust boot groove before boot is installed. (Bendix)

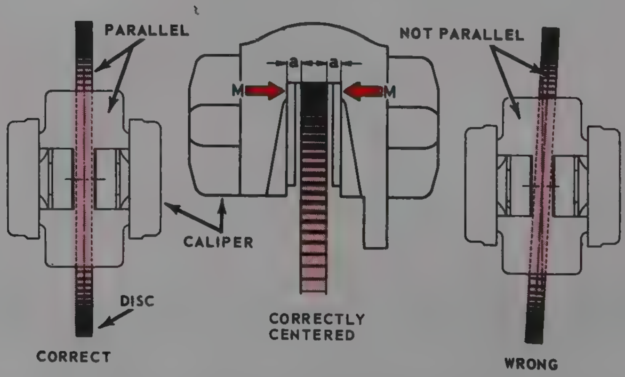


Fig. 31-96. Checking fixed caliper to make certain it is parallel with disc. (Mercedes-Benz)

DISC (ROTOR) INSPECTION

The brake disc (rotor) should be free of excessive or heavy scoring. Some scoring is natural as the disc is not completely protected against the elements. Scoring up to around .015 in. (0.38 mm) deep, as long as the disc is smooth, is permissible. Clean up minor roughness with fine emery cloth. Look at Fig. 31-97.

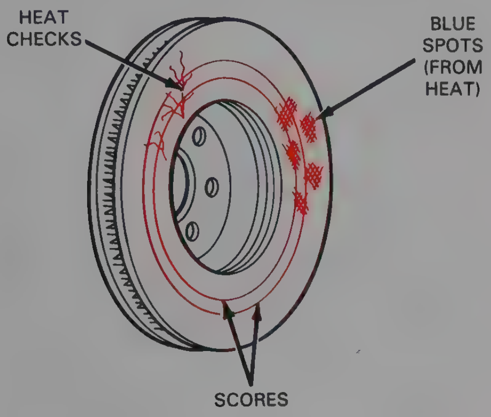


Fig. 31-97. Disc problems. Blue spots and minor scoring can be removed. A crack or series of cracks require disc replacement. (Niehoff)

Check disc for LATERAL RUNOUT (side-to-side wobble). BEFORE CHECKING, SET FRONT WHEEL BEARING CLEARANCE TO JUST REMOVE ANY END PLAY!

Mount dial indicator to a solid surface. Place indicator anvil in about one inch (25.4 mm) from wear surface outer edge. Slowly rotate disc and read dial. Maximum runout should not exceed around .003-.004 in. (0.076-0.102 mm). Refer to Fig. 31-98.

Also check disc for PARALLELISM (same disc thickness all the way around). Using a micrometer, check the disc thickness (in from wear edge about an inch or 25.4 mm) in six or eight spots around the disc. Carefully record each measurement.

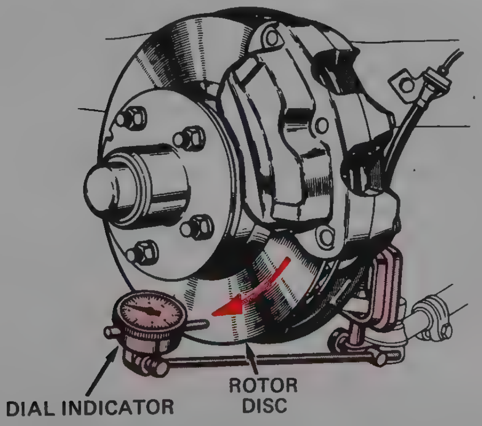


Fig. 31-98. Checking disc (rotor) runout with a dial indicator. (Bendix)

The maximum difference in readings should not exceed .0005 in. (0.013 mm). This may seem a small amount, but anything more than this causes a pulsating brake pedal and possible brake shudder or chatter. A few "specs" call for even smaller amounts – such as .00025 in. (.0064 mm).

DISC MINIMUM THICKNESS

When wear has reduced disc thickness beyond the recommended minimum, the disc should be discarded. This minimum thickness is generally marked on the disc assembly. See Fig. 31-99. NEVER REDUCE TO THIS THICKNESS BY GRINDING – THIS IS THE WEAR LIMIT. MINIMUM GRINDING THICKNESS MUST LEAVE MORE MATERIAL.

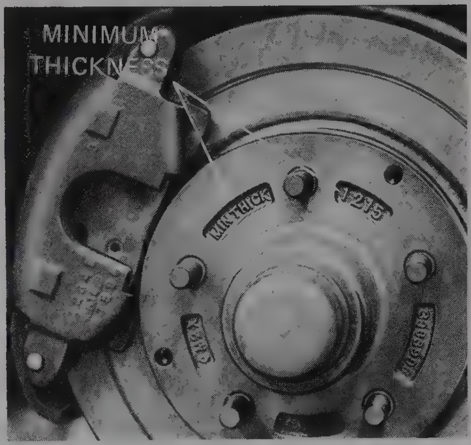


Fig. 31-99. A wear limit showing minimum thickness is marked on disc assembly. (Chevrolet)

TRUING DISC

Measure the disc with a micrometer at 12 different locations around the braking surface to check for PARALLELISM (thickness variations). See Fig. 31-100.

If not worn beyond turning or truing thickness (different than minimum wear thickness), the disc may be turned on a disc refinishing machine. This is shown in Fig. 31-101. This tool cuts both sides of the disc at once, thus reducing the chance of chatter.

Remove only enough stock to clean up disc surface on both sides. Do not reduce thickness beyond recommendations. Follow all machine manufacture's directions. This is a PRECISION operation.

Upon completion of the turning operation, the disc surfaces should be given a nondirectional, crosshatch finish by using proper grinding attachments. Surface should run between 20-80 micro inches with 50 micro inches being about average. See Fig. 31-102.

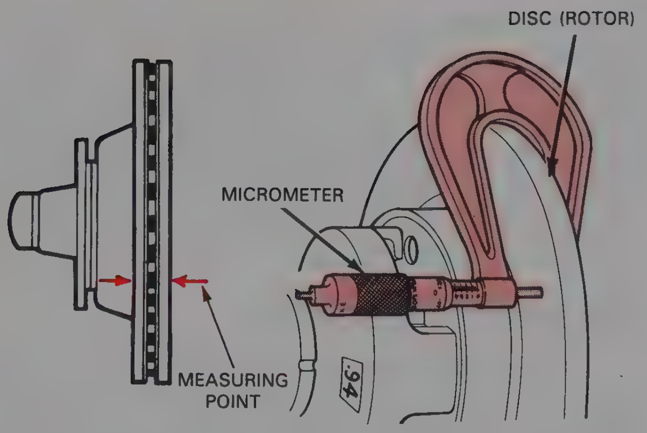


Fig. 31-100. Measuring disc parallelism with micrometer. Measure at twelve equally spaced locations around braking surface. (Niehoff)

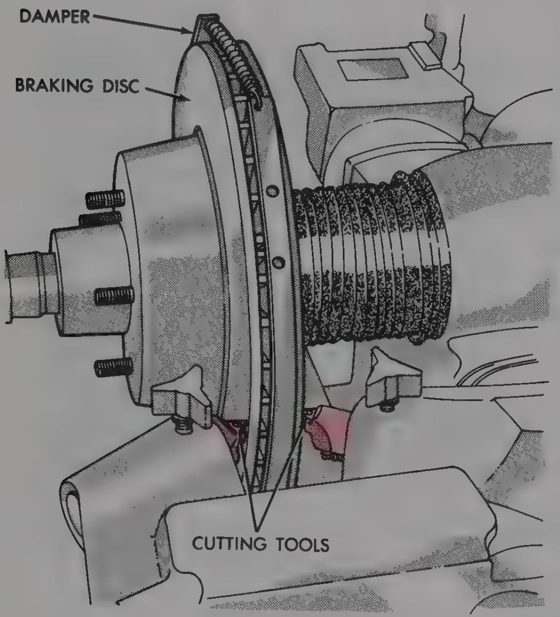


Fig. 31-101. Disc refinishing tool. A cutting tool on each side (straddle cutter) resurfaces both faces of the disc at the same time. Use extreme caution and be sure to keep the machine clean. Always wear safety glasses! (Dodge)

Never resurface one disc. Discs must be done in pairs to ensure smooth, even braking.

When installing a disc, all contact surfaces must be spotless to prevent runout.

DISC BRAKE CAUTIONS

1. Use care when removing wheel to avoid damage to caliper external brake lines.
2. When fitting either oversize or offset wheels, make certain they clear caliper assembly.
3. Adjust front wheel bearings to remove play.
4. Replace fluids siphoned from master cylinder in order to retract pistons.
5. Pump up brakes to bring pads into contact with disc before operating the car.
6. Do not separate caliper halves unless so specified.
7. When removing caliper to pull disc, place cardboard or other suitable block between the pads to prevent pistons from working out of cylinders.
8. Rap caliper during bleeding to help dislodge trapped air.
9. "Riding" the brake will quickly ruin the pads.

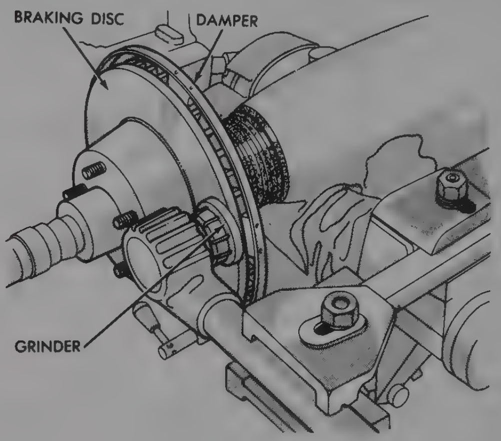


Fig. 31-102. Disc refacing (sanding) machine attachment. This sander will give the disc a 50 micro inch surface and non-directional hatch marks. (Dodge)

10. If the caliper mounting bolts are the prevailing torque type, replace them with new ones.
11. Be CAREFUL when using air to remove caliper piston. Use a THICK pad of cloth. Apply air gradually with little pressure. If piston does not come out, remove air. Rap caliper with soft hammer and try air pressure again. To avoid damage, phenolic (plastic) caliper pistons should be removed by using system hydraulic pressure.

PROPORTIONING VALVE

A proportioning valve is used in brake systems using disc brakes in the front and drums in the rear. Under mild stops, braking effort is about equal front and rear. As pedal pressure is increased, the proportioning valve controls (and finally limits) pressure to the rear wheels. This reduces the possibility of rear wheel lockup during heavy braking.

The proportioning valve can be a separate unit or it can be incorporated into a combination valve.

DUAL PROPORTIONING VALVE

Some vehicles utilize a diagonal split brake system with a dual proportioning valve. The master cylinder is connected directly to the valve. From there, the system is divided diagonally. See Fig. 31-103.

HEIGHT SENSING PROPORTIONING VALVE

The height sensing proportioning valve uses a variable pressure range feature, which increases the pressure to the rear brakes as the vehicle's weight (cargo) increases. This pressure will diminish as the vehicle's weight decreases. Most valves are located on the vehicle's chassis and are connected to the rear axle with a calibrated tension spring or a rod-type linkage. See Fig. 31-103.

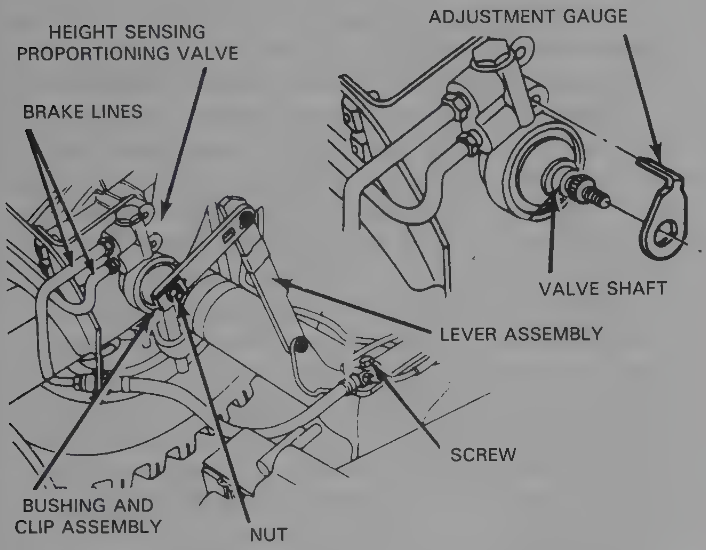

HEIGHT SENSING PROPORTIONING VALVE
ADJUSTMENT GAUGE
BRAKE LINES
VALVE SHAFT
LEVER ASSEMBLY
SCREW
BUSHING AND CLIP ASSEMBLY
NUT

Fig. 31-103. Height sensing proportioning valve assembly. This unit is adjustable; others are not. Some require special bleeding procedures. Follow the manufacturer's service recommendations. (Fram)

Vehicle weight transfer during a stop will cause chassis height-to-axle distance to change. The spring or rod linkage will also change in length. This, in turn, adjusts the valve, limiting pressure to the rear brakes. Loading the vehicle (wood in bed of a truck for example) will also actuate the valve.

DO NOT alter vehicle riding height with air shocks or springs when equipped with this type of proportioning valve. Unsafe braking action could result.

DISC BRAKE METERING VALVE

Systems using disc front and drum rear brakes require the use of a metering valve. See Fig. 31-104.

The metering valve closes off pressure to the front disc brakes until a specified pressure level is generated in the master cylinder. This allows pressure to force the back brake shoes to move into contact with the drum. The rear shoes have some distance to move and spring pressure to overcome. Pressure beyond this opens the metering valve, and both front and rear brakes receive pressure.

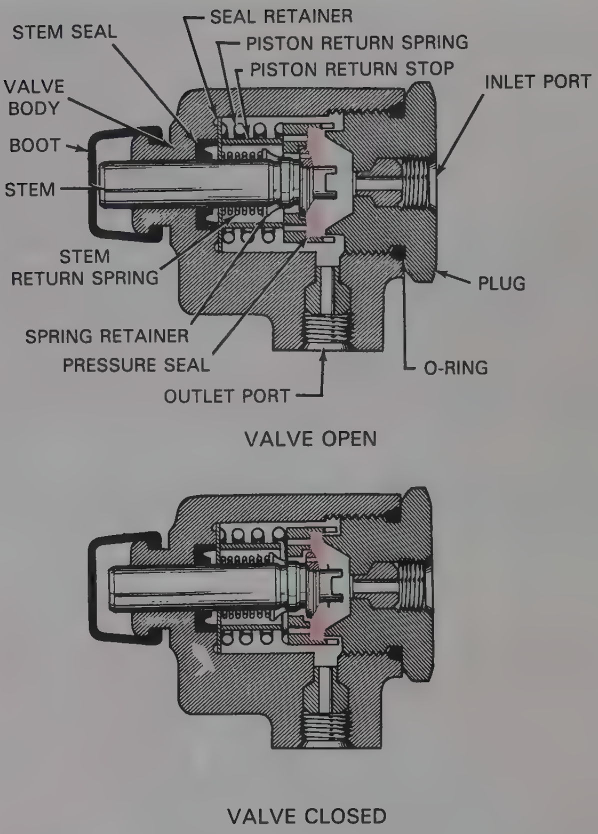

STEM SEAL
SEAL RETAINER
PISTON RETURN SPRING
PISTON RETURN STOP
INLET PORT
VALVE BODY
BOOT
STEM
STEM RETURN SPRING
PLUG
SPRING RETAINER
PRESSURE SEAL
O-RING
OUTLET PORT
VALVE OPEN
VALVE CLOSED

Fig. 31-104. Typical metering valve operation. (Chevrolet)

PRESSURE DIFFERENTIAL SWITCH

Brake systems now use a pressure differential switch to warn the driver that one-half of the system (front or back in most) has failed.

A small piston "floats" in a cylinder separating two pressure chambers. One side of each chamber is connected to one side of the master cylinder. The piston is centered by a spring on each end. An electrical connection, forming the ground switch for the brakes "Failed" warning light, has a terminal that is grounded whenever the piston moves to one side.

Fig. 31-105 illustrates one type of differential pressure switch. It is in the NORMAL "Light Out" position. Each side has developed equal pressure and the piston remains centered.

When one side of the system fails due to a system leak, the pressure drops in one side of the valve. This forces the piston in the direction of the low pressure side. It then touches the electrical plunger and provides the needed ground to light the warning light. See Fig. 31-106.

COMBINATION VALVE

There are two types of combination valves: the TWO FUNCTION VALVE and the THREE FUNCTION VALVE.

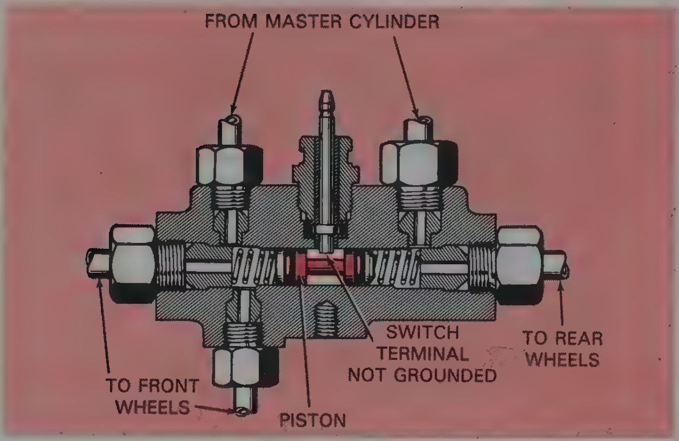

FROM MASTER CYLINDER
SWITCH TERMINAL NOT GROUNDED
TO REAR WHEELS
TO FRONT WHEELS
PISTON

Fig. 31-105. Pressure differential brake warning switch in normal position (no brake failure). Switch terminal not touching piston.

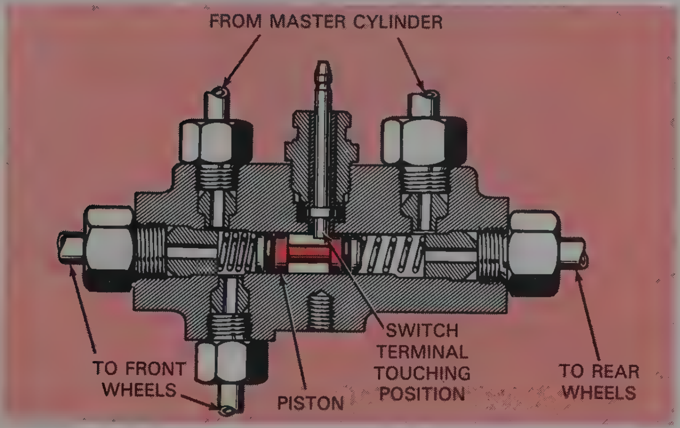

FROM MASTER CYLINDER
SWITCH TERMINAL TOUCHING POSITION
TO FRONT WHEELS
PISTON
TO REAR WHEELS

Fig. 31-106. Pressure differential brake warning switch with one side of system failed. Note how piston is forced towards failed side, thus grounding switch terminal. Warning light would come on. (Chevrolet)

The two function valve combines the metering valve and the brake warning light switch in one unit, Fig 31-107A. Some units may contain a proportioning valve instead of the metering valve.

The three function valve houses the metering valve, the proportioning valve, and the brake warning light switch, Fig. 31-107B. These valves cannot be adjusted or repaired. If they are defective, they must be replaced.

SUMMARY

The master cylinder check valve maintains a residual pressure in the lines (except disc brake section), even when the brake pedal is released.

Use a complete checklist when doing a brake inspection. Inspect the master cylinder, brake pedal, stoplight switch, wheel cylinders, calipers, brake lining, brake drums, brake rotors, seals, brake lines and hoses, parking brake, switches, valves, and chassis components. Also, road test the car. Be thorough. Never perform halfway jobs.

Modern master cylinders are usually the double piston (tandem) type. The tandem cylinder provides an extra measure of safety.

Master cylinder must not leak, externally or internally. The fluid level must be within 3/8 in. (9.53 mm) of the reservoir top. Compensating port must be open when brake pedal is fully released. Residual check valve must function.

Master cylinder can often be repaired by cleaning and installing a repair kit.

Use denatured alcohol for cleaning master cylinder, wheel cylinders, and calipers. Use crocus cloth to clean up minor corrosion and scratches in master cylinder, wheel cylinders, and calipers. DO NOT use crocus cloth or sandpaper on aluminum master cylinder or wheel cylinders. If damaged, they must be replaced. Light

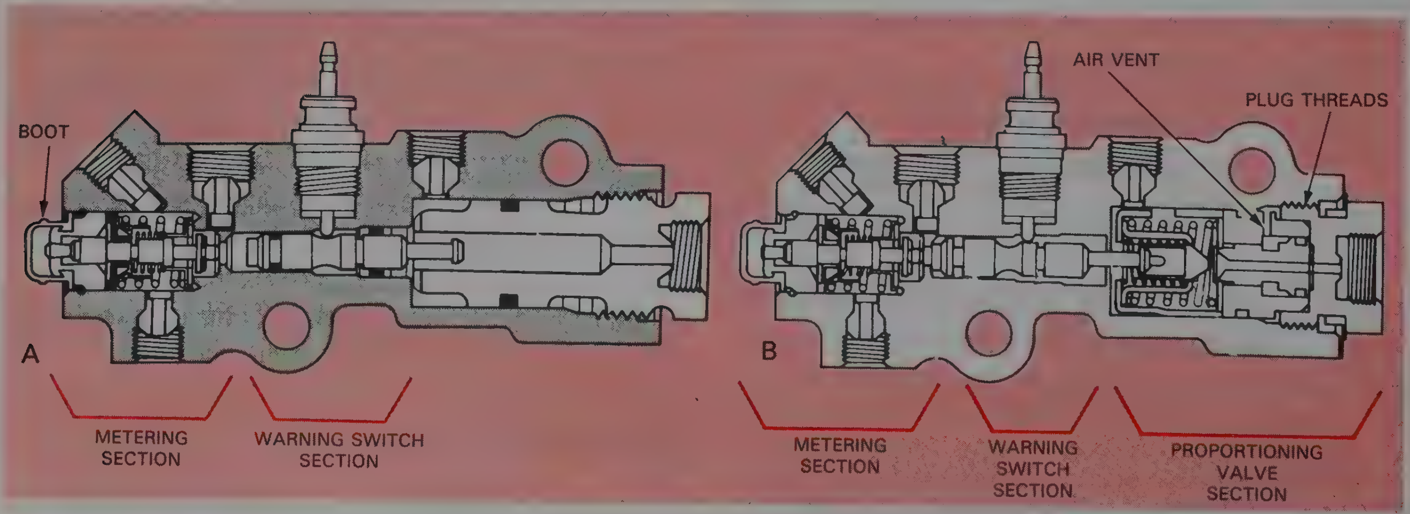

BOOT
A
METERING SECTION
WARNING SWITCH SECTION
AIR VENT
PLUG THREADS
B
METERING SECTION
WARNING SWITCH SECTION
PROPORTIONING VALVE SECTION

Fig. 31-107. The two types of combination valves are the two function valve (A) and the three function valve (B). When servicing the brakes, always inspect these valves for leakage inside the boot and around the fittings. (Bendix)

honing (not on aluminum components), followed by polishing with crocus, is possible in many cases. Use brake fluid on the hone stones. Clean cylinder thoroughly to remove abrasive.

Discard cylinders showing more than .005 in. (0.127 mm) clearance between cylinder wall and piston or that show pitting, corrosion, or scratches that are not removed during the honing. Remove burrs from cylinder ports. Before assembling cylinders, coat pistons and cups with fresh brake fluid.

Keep brake fluid away from car's painted surfaces.

If there is the slightest doubt as to the advisability of repairing a cylinder — throw it away!

Brake pedal height and free play must be correct.

Check operation of power booster where used. Efficient booster operation depends upon a sound unit and a normal vacuum or hydraulic source, depending upon booster type. Check lines for leaks.

Air used to blow brake cylinders dry must be free of water and oil. This is most important. If it is not, finish with an alcohol rinse and allow to air dry.

Always disassemble and rebuild or replace wheel cylinders at every brake reline job. Install new grease seals at every brake reline.

The brake design in wide use today is the self-energizing, duo-servo, single-fixed anchor, self-adjusting type.

The forward or primary shoe is the first shoe from the wheel cylinder in the direction of forward rotation. This is generally the front shoe. The reverse or secondary shoe is generally the rear shoe (faces toward rear of car). On duo-servo brakes, the primary shoe will have a shorter section of lining.

Study the wheel brake shoe assembly before removal. Keep all parts together. Use proper tools. Clamp wheel cylinder.

Lining may be affixed to the shoes by bonding or by riveting.

When riveting lining, make certain shoe is in good shape, that proper lining is applied, and that tubular rivets of the correct length are used. Use a roll set to firmly set rivets. Keep lining in firm contact with shoe while riveting.

Check lining to shoe fit with a feeler gauge.

Always use top quality lining.

Lined shoes should be ground for a proper fit. Lining is generally contour ground to around .040 in. (1.02 mm) under drum diameter for servo brakes. For non-servo, it may be ground to .020 to .030 in. (0.508 to 0.762 mm) under drum diameter.

When installing shoe assemblies, clean and lubricate shoe support pads. Lube push rod-to-shoe, adjuster, adjuster-to-shoe, and hold-down areas. Lube sparingly and only with special high temperature grease.

Install shoes in their correct locations. Install springs, hold-downs, and other parts. Springs must be in good condition and in the proper position. Keep shoe lining free of oil and grease.

A minor brake adjustment consists merely of adjusting lining-to-drum clearance. A major adjustment involves centering the shoes through movement of the anchor or anchors, and then setting lining-to-shoe clearance. Major adjustments are never required on self-centering brakes.

Never adjust brakes too close. Some anchor pins are adjusted by rotating (eccentric type) or by moving up and down (slotted type). Shoes must be properly centered in the drum.

Self-adjusting brakes need only an initial adjustment following relining. They will then maintain correct clearance for life of the lining.

Adjustment slots for moving the star wheel may be in the backing plate or in the brake drum.

Brake drums must be free of cracking, excessive scoring, and heavy heat checking. Drum should not be more than .010 in. (0.254 mm) out-of-round nor should taper exceed .005 in. (0.127 mm).

Drums may be trued by turning or grinding. Remove only enough metal to clean up the drum. Never remove more than .060 in. (1.524 mm).

When a drum on one side needs truing, turn the one on the other side to the same size.

Drums turned to .030 in. (0.762 mm) or larger oversize require the use of thicker lining or shim stock under the lining.

Clean drums thoroughly after turning or grinding.

Metallic type brake lining requires heat resistant springs and a 20 micro inch drum finish.

Keep parking brake adjusted. Do not set up too tight. Adjust after adjusting service brakes.

When replacing a brake line, use double-wrapped, coated steel tubing only. Use double-lap or I.S.O. flares only. Protect tubing from vibration. Avoid sharp bends. Keep away from moving parts and heat.

Stoplight switch must work with a small movement of the brake pedal. Switch must not prevent full pedal release.

Use DOT approved brake fluid.

Brakes may be bled manually or with a pressure bleeder. Bleed until clear fluid, with no air bubbles, appears. Never reuse fluid.

Brake systems may be flushed with alcohol (bleed until all alcohol is removed) and then filled with fresh brake fluid.

Bleed cylinder farthest from master cylinder first. If power brake has bleeder valve, bleed it first. On split systems (tandem cylinders), bleed the wheel cylinders served by the primary piston first. Exhaust the vacuum in power brake systems before bleeding. Anti-lock brake systems require special bleeding techniques.

When removing wheel assemblies from disc brakes, use care to avoid damage to caliper brake lines.

Some disc brake caliper halves must not be separated. Some calipers require removal to change the friction pads. Others do not.

Siphon fluid from the master cylinder reservoir before forcing pad pistons inward.

If caliper is removed, check for mounting shims. Never replace one-half of a caliper.

If caliper cylinders cannot be cleaned with crocus cloth, discard caliper.

When installing caliper, use shims in their original location. Check caliper for proper centering over disc. Caliper must also be parallel to disc.

Check disc for excessive scoring, wear, and runout.

Following installation of new pads, pump up brakes to force pads against disc before driving car. Pedal should be firm.

Keep front wheel bearings adjusted to manufacturer's "specs." Wheel bearing adjustment is especially critical on disc brake jobs.

Replace brake fluid siphoned from master cylinder with fresh fluid.

Do not attempt overhaul of metering valve, differential pressure switch, or proportioning valve. If defective, replace.

PROBLEM DIAGNOSIS

PROBLEM: NO PEDAL — NO BRAKES

Possible Cause	Correction
1. Broken line, hose, or other leak.	1. Repair source of leak.
2. Air in system.	2. Bleed system. Repair source of air entry.
3. Lining and/or pads worn.	3. Adjust or reline.
4. Master cylinder cups leaking.	4. Rebuild or replace master cylinder.
5. Low fluid level in master cylinder.	5. Fill reservoir and bleed system.
6. Brake linkage disconnected.	6. Connect.
7. Automatic shoe adjusters not functioning.	7. Repair or replace adjusters. Adjust shoes.
8. Vaporized fluid from excessive braking.	8. Allow to cool. Install super heavy-duty fluid.
9. Caliper seal or piston damage.	9. Repair or replace as needed.

PROBLEM: SPONGY PEDAL

Possible Cause	Correction
1. Air in system.	1. Bleed system. Repair source of air entry.
2. Shoes not centered in drum.	2. Adjust anchors to center shoes.
3. Drums worn or turned until too thin.	3. Replace drums.
4. Soft hose.	4. Replace hose.
5. Shoe lining wrong thickness.	5. Install correct lining and grind.
6. Cracked brake drum.	6. Replace drum.
7. Brake shoes distorted.	7. Replace shoes.
8. Insufficient brake fluid.	8. Bleed system. Fill with fluid.
9. Bent pads.	9. Replace pads.

PROBLEM: HARD PEDAL (EXCESSIVE FOOT PRESSURE REQUIRED)

Possible Cause	Correction
1. Incorrect lining.	1. Install proper lining.
2. Linings contaminated with grease or brake fluid.	2. Replace or reline shoes. Repair source of leak.
3. Shoes not centered.	3. Center shoes.
4. Primary and secondary shoes reversed.	4. Install shoes in correct location.
5. Brake linkage binding.	5. Free and lubricate.
6. Master or wheel cylinder pistons frozen.	6. Rebuild or replace cylinder.
7. Linings hard and glazed.	7. Sand lining with medium grit sandpaper.
8. Lining ground to wrong radius.	8. Grind lining as specified.
9. Brake line or hose clogged or kinked.	9. Replace.
10. Power booster unit defective.	10. Repair or replace power booster.
11. No vacuum to power booster.	11. Replace clogged, soft lines. Repair leaks.
12. Engine fails to maintain proper vacuum to booster.	12. Tune or overhaul engine.
13. Pads worn excessively thin.	13. Replace pads.
14. Seized caliper piston(s).	14. Repair or replace.
15. Heat checked or blued rotor.	15. Recondition or replace rotor.
16. Faulty proportioning valve.	16. Replace valve.
17. Quick take-up valve center orifice clogged.	17. Replace master cylinder.

PROBLEM: BRAKES GRAB (ONE OR MORE WHEELS)

Possible Cause	Correction
1. Grease or brake fluid on lining and/or pads.	1. Replace lining and/or pads.
2. Lining charred.	2. If mild, sand. If severe, reline.
3. Lining loose on shoe.	3. Reline.
4. Loose wheel bearings.	4. Adjust wheel bearings.
5. Defective wheel bearings.	5. Replace bearings.
6. Loose brake backing plate.	6. Torque fasteners.
7. Defective drum.	7. Turn drum. Turn drum on opposite side also.
8. Sand or dirt in brake shoe assembly.	8. Disassemble and clean. Sand linings and drum. Blow clean.
9. Wrong lining.	9. Install correct lining.
10. Primary and secondary linings or shoes reversed.	10. Install correctly.
11. Loose caliper.	11. Tighten to specifications.
12. Defective power brake.	12. Repair or replace.
13. Tires inflated unequally.	13. Inflate to specifications.

PROBLEM: BRAKES FADE

Possible Cause	Correction
1. Poor lining and/or pads.	1. Install quality lining and/or pads designed for the job.
2. Excessive use of brakes.	2. Use lower gears, reduce speed or load.
3. Poor brake fluid.	3. Flush. Install super heavy-duty fluid.
4. Improper lining-to-drum contact.	4. Adjust shoes or grind to correct radius.
5. Thin brake drums.	5. Install new drums.
6. Dragging brakes.	6. Adjust or repair other cause of dragging.
7. Riding the brake pedal.	7. Keep foot off brake pedal unless needed.
8. Excessively thin rotors.	8. Replace rotors.

PROBLEM: BRAKES PULL CAR TO ONE SIDE

Possible Cause	Correction
1. One wheel grabbing.	1. (See Brakes Grab.)
2. Shoes not centered or adjusted properly.	2. Center and adjust lining-to-drum clearance.
3. Different lining on one side or shoes reversed on one side.	3. Replace lining or install shoes in proper position.
4. Plugged line or hose.	4. Clean or replace.
5. Uneven tire pressure.	5. Use same pressure on both sides.
6. Front end alignment out.	6. Align front end.
7. Sagged, weak, or broken spring. Weak shock absorber.	7. Install new spring or shocks.
8. Wheel cylinder bore diameter different on one side.	8. Install correct size cylinder.
9. Pads contaminated with grease or brake fluid.	9. Replace pads.
10. Caliper or backing plate loose.	10. Tighten to specs.

PROBLEM: BRAKES DRAG

Possible Cause	Correction
1. Parking brake adjusted too tight.	1. Adjust properly.
2. Clogged hose or line.	2. Clean or replace.
3. Master cylinder reservoir cap vent clogged.	3. Open vent in cap.
4. Brake pedal not fully releasing.	4. Adjust pedal release.
5. Insufficient pedal free travel.	5. Adjust pedal free travel so that compensating port will be open when brake is released.
6. Brakes adjusted too tight.	6. Adjust correctly.
7. Brakes not centered in drum.	7. Center shoes.
8. Master cylinder or wheel cylinder cups soft and sticky.	8. Rebuild or replace cylinders. Flush system.
9. Loose wheel bearing.	9. Adjust bearings.
10. Parking brake fails to release.	10. Clean and lubricate parking brake linkage.
11. Shoe retracting springs weak or broken.	11. Replace springs.
12. Out-of-round drum.	12. Turn drum.
13. Defective power booster.	13. Repair or replace booster.
14. Seized caliper piston(s).	14. Repair or replace.
15. Sliding caliper bound.	15. Free caliper. Clean sliding surfaces. Lubricate if required by manufacturer.

16. Thin rotor.	16. Replace rotor.
17. Loose caliper bolts.	17. Tighten to specifications.
18. Bent pads.	18. Replace pads.
19. Improper or contaminated brake fluid.	19. Repair as necessary.

PROBLEM: "NERVOUS" PEDAL (PEDAL MOVES RAPIDLY UP AND DOWN WHEN APPLYING BRAKES)

Possible Cause	Correction
1. Brake drums out-of-round.	1. Turn drums — in pairs.
2. Excessive disc runout.	2. Machine or replace disc.
3. Loose wheel bearings.	3. Adjust to remove play.
4. Drums loose.	4. Tighten wheel lugs.
5. Rear axle bent.	5. Replace axle.
6. Brake assembly attachments loose or missing.	6. Repair as necessary.

PROBLEM: BRAKES CHATTER

Possible Cause	Correction
1. Weak or broken shoe retracting springs.	1. Replace springs.
2. Defective power booster.	2. Repair or replace booster.
3. Loose backing plate.	3. Tighten fasteners.
4. Loose or damaged wheel bearings.	4. Adjust or replace bearings.
5. Drums tapered or barrel shaped.	5. Turn drum in pairs.
6. Bent shoes.	6. Replace shoe or shoes.
7. Dust on lining.	7. Sand. Blow clean.
8. Lining glazed.	8. Sand. Blow clean.
9. Drum damper spring missing.	9. Install damper spring.
10. Grease or fluid on linings.	10. Reline brakes.
11. Shoes not adjusted properly.	11. Center and adjust shoes.
12. Incorrect pads.	12. Install correct pads.
13. Damaged pads.	13. Replace pads.
14. Damaged rotors.	14. Replace or repair rotors.

PROBLEM: BRAKES SQUEAL

Possible Cause	Correction
1. Glazed or charred lining and/or pads.	1. Sand or replace lining and/or pads.
2. Dust or metal particles imbedded in lining.	2. Sand lining and blow clean.
3. Lining rivets loose.	3. Install new lining rivets properly.
4. Wrong lining.	4. Install correct lining.
5. Shoe hold-downs weak or broken.	5. Replace hold-down.
6. Drum damper spring missing.	6. Install damper spring around drum.
7. Shoes improperly adjusted.	7. Adjust shoes.
8. Shoes bent.	8. Install new shoes.
9. Bent backing plate.	9. Install new backing plate.
10. Shoe retracting springs weak or broken.	10. Replace springs.
11. Drum too thin.	11. Install new drum.
12. Lining saturated with grease or brake fluid.	12. Replace lining. Repair leaks.
13. Pad wear sensors contacting caliper.	13. Replace pads. Machine rotor if necessary.
14. Rotor contacting caliper.	14. Check for loose fasteners, missing shims, and other problems. Correct as required.
15. Loose outboard pads.	15. Bend tabs to tighten. Replace if tabs are broken.

PROBLEM: SHOES CLICK

Possible Cause	Correction
1. Shoe is pulled from backing plate by following tool marks in drum.	1. Smooth drum braking surface.
2. Shoe bent.	2. Replace shoe.
3. Shoe support pads on backing plate grooved.	3. Smooth and lubricate pads or replace backing plate.

PROBLEM: BRAKE WARNING LIGHT COMES ON

Possible Cause	Correction
1. Air in system.	1. Check for reason and bleed system.
2. Malfunctioning master cylinder.	2. Repair or replace as necessary.

3. Worn out brake lining.	3. Replace lining.
4. Defective shoe adjusters.	4. Repair or replace as necessary.
5. Contaminated or improper brake fluid.	5. Repair as necessary.
6. Anti-lock brake system malfunction.	6. Refer to manufacturer's diagnosis and service recommendations.

PROBLEM: AUTOMATIC SHOE ADJUSTERS WILL NOT FUNCTION

Possible Cause	Correction
1. Adjuster wheel (star wheel) rusty or dirty.	1. Clean threads. Lube with high temperature grease.
2. Parts installed wrong.	2. Install correctly.
3. Adjuster lever dirty and sticky.	3. Clean and lube.
4. Star wheel notches burred.	4. Install new star wheel.
5. Adjuster lever bent.	5. Install new adjuster lever.

KNOW THESE TERMS

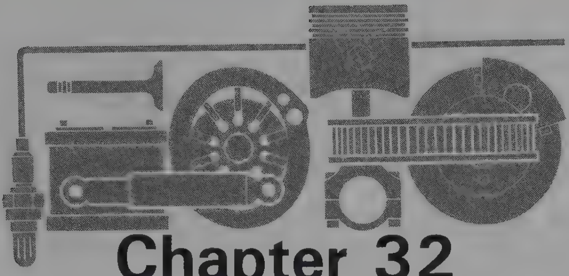
Static line pressure, Compensating port, Breather port, Secondary piston, Quick take-up master cylinder, Bench bleeding, Pressure bleeding, Brake pedal height, Power brakes, Hydro-boost, Servo brake, Non-servo brake, Self-centering brakes, Star wheel, Concentric grinding, Eccentric grinding, Slotted anchor, Scoring, Heat checking, Barrel wear, Double-lap flare, I.S.O. flare, Bleeder screw, Surge bleeding, Rotor, Transfer tube, Fixed caliper, Floating caliper, Pads, Caliper alignment, Rotor lateral runout, Rotor parallelism, Micro inch finish, Proportioning valve, Metering valve, Pressure differential switch, Combination valve, Brake fade, Spongy pedal.

QUIZ - Chapter 31

1. Residual pressure in the brake lines is maintained by the:
   a. Proportioning valve.
   b. Master cylinder check valve.
   c. Master cylinder compensating port.
   d. Slight pressure on brake pedal.
2. List ten important items to be checked during a brake inspection.
3. A tandem master cylinder:
   a. Provides greater braking power.
   b. Applies pressure to separate front and rear systems.
   c. Works the clutch also.
   d. Has two cylinders, one on top of the other.
4. When the brake pedal is fully released, the __________ __________ in the master cylinder must be open to relieve pressure buildup in the system.
5. Use __________ __________ for cleaning master and wheel cylinders.
6. Fluid level in the master cylinder should be:
   a. 3/8 in. (9.5 mm) from top.
   b. At the top.
   c. 2 in. (51 mm) from top.
   d. Running over slightly.
7. Use __________ cloth to remove slight corrosion and scratches in wheel and master cylinders.
8. If the cylinders are honed, use __________ __________ as a stone lubricant.
9. The maximum allowable clearance between a brake cylinder piston and its cylinder wall is:
   a. .010 in. (0.254 mm).
   b. .050 in. (1.270 mm).
   c. .005 in. (0.127 mm).
   d. .001 in. (0.025 mm).
10. Following honing, remove __________ from ports.
11. Brake fluid will __________ the paint on a car.
12. Wheel cylinders should be rebuilt or replaced at every brake reline. True or False?
13. The forward or primary shoe generally faces:
    a. The back of the car.
    b. Up.
    c. Down.
    d. The front of the car.
14. Brake springs are all alike and may be installed at random. True or False?
15. The brake in wide use today is the:
    a. Duo-servo, fixed anchor, self-adjusting.
    b. Non-servo, single adjustable anchor.
    c. Self-energizing, duo-anchor, self-centering.
    d. Huck.
16. Lining may be attached to shoes by __________ or by __________.
17. Shoe lining must be kept free of __________ and __________.
18. A minor brake adjustment involves centering and adjusting the shoes. True or False?
19. Lined shoes are generally __________ ground.
20. Self-centering brakes require a major adjustment following shoe relining. True or False?
21. A cracked brake drum can be salvaged by welding. True or False?
22. Drums showing more than __________ out-of-roundness or __________ taper should be turned or ground.
23. Front and rear drums must be the same diameter.

True or False?

24. Never increase drum diameter by more than ___________.
25. When a drum on one side is turned, the drum on the opposite side should be turned to the same diameter. True or False?
26. Adjust parking brake before adjusting service brakes. True or False?
27. When replacing a brake line use:
    a. Copper tubing.
    b. Brass tubing.
    c. Double-wrapped steel tubing.
    d. Single-wall steel tubing.
28. Pressure bleeding requires two people. True or False?
29. Normally, first bleed the wheel cylinder:
    a. Closest to the master cylinder.
    b. On the same side as the master cylinder.
    c. Farthest away from the master cylinder.
    d. On the left front side.
30. When bleeding systems using a tandem cylinder, bleed wheel cylinders served by master cylinder ___________ piston first.
31. Fluid bled from the system may be used again if it is strained. True or False?
32. All disc brake calipers must be removed to change pads. True or False?
33. Before forcing caliper pistons away from the disc, _________ _________ from the _________ _________.
34. Caliper must be centered over and parallel with the disc. True or False?
35. Disc brakes require that front wheel bearing be:
    a. Adjusted with .006 in. (0.152 mm) end play.
    b. Adjusted so that no play is present.
    c. Lubricated every 2,000 miles (3 218 km).
    d. Preloaded to 60 foot-pounds (81 N·m).
36. Following installation of new pads, always pump the brakes to force the ___________ out against the ___________ before driving the car.
37. After relining, make 8 or 10 stops from high speed to seat linings. True or False?
38. The ___________ ___________ master cylinder supplies a large volume of _________ ___________ fluid at the start of brake application.
39. Air pressure is the recommended way to remove phenolic (plastic) pistons from calipers. True or False?
40. Some nylon master cylinder reservoirs have a ___________ so fluid level can be easily and quickly checked.
41. Aluminum wheel cylinders may be honed. True or False?
42. The Hydro-Boost unit generally receives necessary operating pressure from the _____________ _____________ _____________.
43. The _____________ proportioning valve incorporates a variable pressure range feature to prevent brake lockup.
44. A dual proportioning valve is used on a______.
    a. Single master cylinder.
    b. Hydro-Boost unit.
    c. Diagonal split brake system.
    d. None of the above.



Chapter 32

WHEELS, BEARINGS, TIRES

After studying this chapter, you will be able to:

☐ Explain the importance of wheel alignment.
☐ Describe the construction, operation, and service of wheel bearings.
☐ Explain tire and wheel construction and service.
☐ Summarize wheel alignment procedures.
☐ Diagnose common wheel and tire related problems.

WHEEL ALIGNMENT

Wheel alignment refers to the various angles formed by the front and rear wheels, spindles, and steering arms.

Correct alignment is vital. Improper alignment can cause hard steering, pulling to one side, wandering, noise, and rapid tire wear.

The various alignment angles, (caster, camber, toe-in, steering axis inclination, and toe-out on turns) are all related. A change in one can alter the others.

Some of the angles (caster, camber, and toe-in) are adjustable. Others (steering axis inclination, toe-out on turns) are built-in and are thus nonadjustable.

When checking and adjusting wheel alignment, use quality equipment that is in good condition. Wheel alignment is a PRECISION operation; both equipment and techniques must be perfect.

PREALIGNMENT CHECKS

Many complaints of improper wheel alignment can be traced to other nonrelated areas or items. Before assuming that wheel alignment is responsible, always make the following checks:

Inspect the tires for wear, bulging, or other damage. Tire size and pressure must be as specified. Never attempt to align a car when one of the front tires is worn and the other has good tread. Check the front wheel bearings for damage or looseness. Spin wheels and check for excessive radial and lateral runout as well as static and dynamic unbalance. Tighten wheel lugs. (See section on wheel bearing and tire service later in this chapter.)

Check the ball joints, kingpins, and struts for excessive wear. Inspect other suspension parts for wear or damage.

Examine the steering system (gearbox, gearbox-to-frame fasteners, tie rod and drag link ball sockets, idler arms bushings, pitman arm, or rack and pinion setup. Check for wear, improper adjustment, or loose fasteners. Check power steering action.

Check the shock absorbers for proper damping action. Inspect for leaks.

Look for broken or sagged springs, worn shackles, or control arm bushings. (See chapter on steering and suspension system service.)

PREPARING CAR FOR WHEEL ALIGNMENT CHECKS

To insure accurate alignment checks and adjustments, the car must be at curb weight. CURB WEIGHT is the weight of the car with all normal accessories, full tank of gas, spare tire, and without driver or passengers. Check interior and trunk areas and remove luggage, sporting goods, and other items to maintain correct curb weight.

CURB HEIGHT, also called trim height, is the standing height of car at curb weight. It must be as specified. Replace broken or sagged springs as needed.

TIRE PRESSURE must also be as specified.

Vehicles equipped with torsion bars must be checked for proper height. Place car on a level surface, bounce both ends of car (from center of bumpers) and allow car to come to normal rest position. Attach checking gauges and adjust torsion bars as required. One form of check is shown in Fig. 32-1.

ALIGNMENT HEIGHT SPACERS

Some makers recommend the use of alignment height spacers when checking camber and caster. They are not used for toe-in setting.

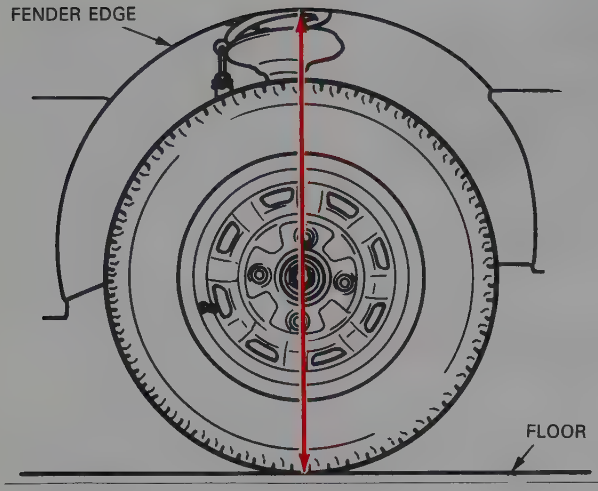

FENDER EDGE
FLOOR

Fig. 32-1. Checking trim height on a vehicle with MacPherson strut front suspension. (Geo)

Adjust spacers to the proper length. Place them in the designated positions (both sides, front and back) and curb height will be exact. If specifications call for alignment spacers, use them. Fig. 32-2 illustrates the use of a typical alignment spacer in place between the frame and rear axle housing.

Do not forget to remove alignment spacers following completion of alignment.

The use of alignment spacers does not take the place of replacing broken or sagging springs. All prealignment checks and corrections must be made as required.

BOUNCING BEFORE ALIGNMENT

Many manufacturers specify bouncing both front and rear of car (at center of bumpers). This allows the car to come to its normal rest position before making alignment checks. See Fig. 32-3.

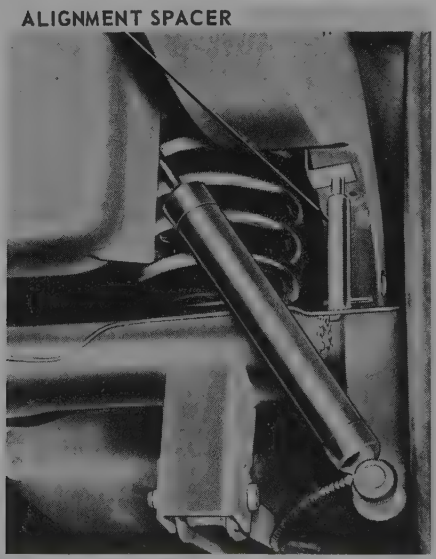

ALIGNMENT SPACER

Fig. 32-2. Alignment spacer must be of exact length and installed in specified location. (Ford)

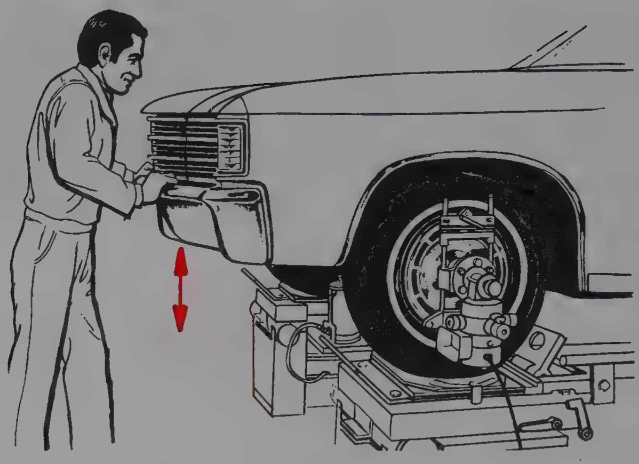


Fig. 32-3. Bounce car, both front and rear, in center of bumper. Allow it to come to normal curb height before making alignment checks. With this method, no alignment spacers are used. (Hunter)

CHALK MARK POINT OF GREATEST LATERAL RUNOUT

Spin a front wheel. Slowly move chalk marker toward the side of the tire until it just contacts the point of greatest lateral runout. Stop wheel and mark this spot plainly. The mark must be at the top when checking toe-out on turns. Mark must be in a horizontal position when checking caster and camber. Look at Fig. 32-4.

CASTER

Caster may be defined as the tilting of the spindle support centerline from true vertical, as viewed from the side of the vehicle.

When the spindle is tipped so that the support centerline intersects the roadway at a point (lead point) ahead

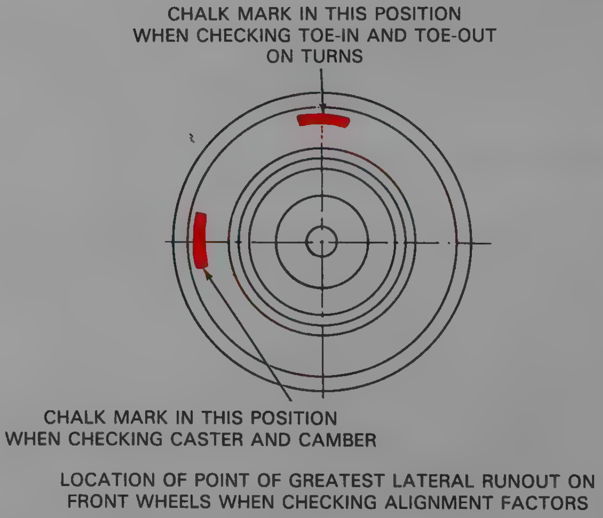

CHALK MARK IN THIS POSITION WHEN CHECKING TOE-IN AND TOE-OUT ON TURNS
CHALK MARK IN THIS POSITION WHEN CHECKING CASTER AND CAMBER
LOCATION OF POINT OF GREATEST LATERAL RUNOUT ON FRONT WHEELS WHEN CHECKING ALIGNMENT FACTORS

Fig. 32-4. Chalk mark point of greatest lateral runout. Note location of mark during various checks.

the side of the vehicle.

When the spindle is tipped so that the support centerline intersects the roadway at a point (lead point) ahead of the actual tire contact point, the caster is called POSITIVE. Tilting the spindle so that the support centerline strikes the road behind the tire contact point produces NEGATIVE caster.

The spindle support centerline may be assumed to be a line drawn through the center of the spindle ball joints or through the center of the kingpin where used. Fig. 32-5 depicts a POSITIVE caster angle.

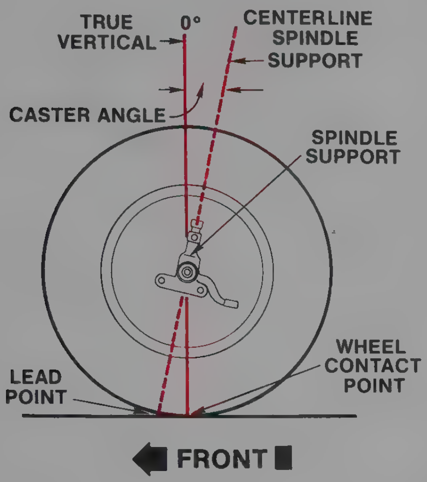


Fig. 32-5. Positive caster angle. (Moog)

Both positive and negative caster angles are illustrated in Fig. 32-6.

Caster, either positive or negative, is measured in degrees from true vertical.

Positive caster tends to assist the wheels in maintaining a straight ahead position.

Many manufacturers specify negative caster. The steering axis inclination angle will provide sufficient tracking stability despite the lack of positive caster.

Always set caster exactly as specified. Make certain both sides are alike within 1/2 deg. Due to the normal "crown" (hump in center) of most roads, handling is often improved by deliberately setting the driver's side caster to 1/2 deg. less (when specs call for positive setting) or 1/2 deg. more (when specs call for negative setting) than that used on the passenger's side. REGARDLESS OF SETTING VARIATION TO COMPENSATE FOR ROAD CROWN, SETTINGS MUST BE WITHIN THE MANUFACTURER'S SPECIFIED RANGE AND WITH NO MORE THAN 1/2 DEG. DIFFERENCE BETWEEN SIDES.

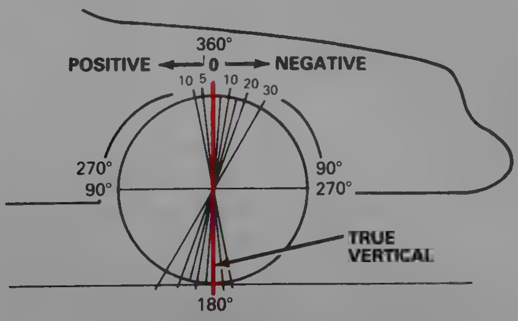


Fig. 32-6. Positive and negative caster in relation to true vertical. (Pontiac)

CHECKING CASTER ANGLE

Place the wheel so that the chalk mark indicating the point of greatest wheel runout is in the horizontal position, Fig. 32-4. Using accurate equipment, carefully check caster angle. Follow manufacturer's instructions for use of the equipment. Repeat on other wheel. Fig. 32-7 illustrates the use of one form of caster gauge.

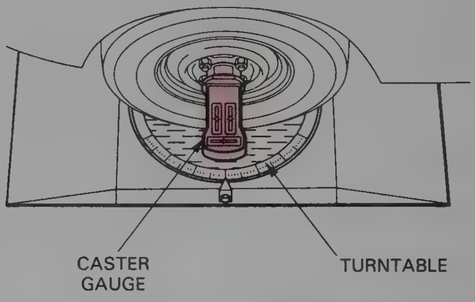


Fig. 32-7. One setup for checking caster angle. (Toyota)

PROBLEMS CREATED BY IMPROPER CASTER ANGLE

Hard steering, wandering, high speed instability, pull to the right or left (towards side with least caster) can be caused by improper caster angles. Improper caster angles will not cause tire wear.

CAMBER

Camber is the tilting of the wheel centerline, viewed from the front of the car, away from a true vertical line. When the top of the wheel is tilted outward (away from car), camber is said to be POSITIVE. When the top of the wheel is tilted inward, camber is NEGATIVE, Fig. 32-8. Both positive and negative camber are illustrated in Fig. 32-9.

It is important to note that positive camber tends to place the tire-to-road contact area nearer to the point of load. This makes for easier steering and forces the thicker inner portion of the spindle to carry the majority of the load.

Modern suspension design has reduced the need for considerable positive camber. In fact, many car makers

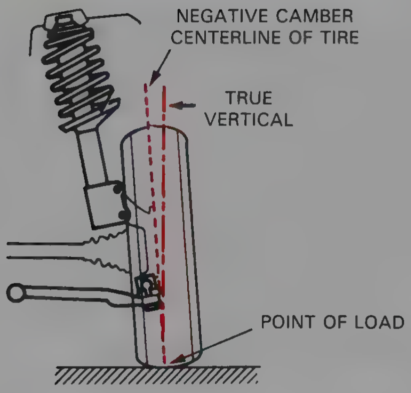


Fig. 32-8. Negative camber is shown. Note that top of tire is tilted inward. (Chevrolet)

specify a slight amount of negative camber.

Camber angles, positive or negative, are usually quite small, averaging from around 1/2 deg. positive to 1/4 deg. negative.

Makers often recommend setting around 1/4 to 1/2 deg. more positive camber in the left wheel to compensate for normal road camber (crown). In that the car will tend to pull toward the side with greater positive camber, the pull effect of the crowned road will be offset.

Improper camber can cause tire wear, as discussed later.

CHECKING CAMBER

Place the chalk mark on the tire (showing point of greatest lateral runout) in a horizontal position. Bounce car, front and back, to bring to normal curb height. Install alignment spacers if required.

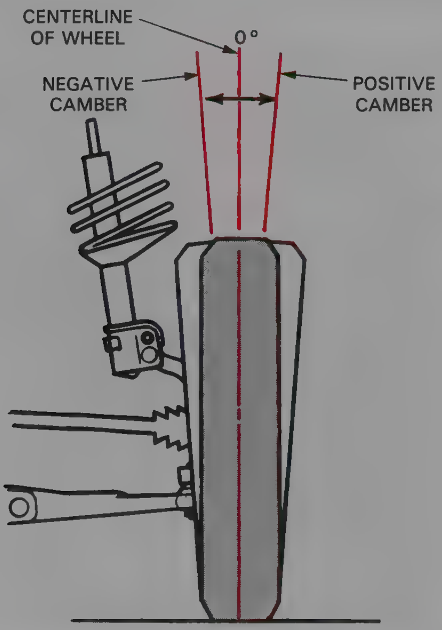


Fig. 32-9. Positive and negative camber on one front-wheel drive arrangement. (Buick)

Wheels must be in the STRAIGHT AHEAD position and on a LEVEL surface. Use equipment as directed by the manufacturer. Fig. 32-10 shows one type of camber checking tool. Note chalk mark on tire.

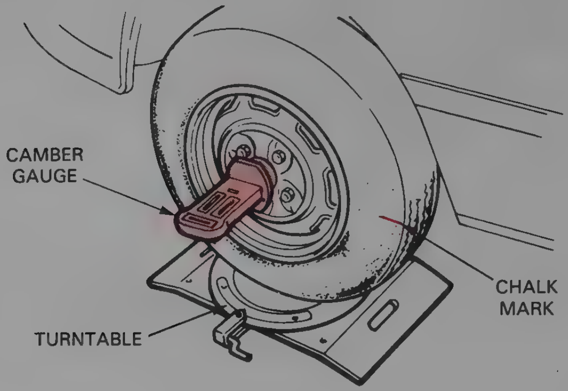


Fig. 32-10. Camber gauge attached to wheel. Be sure wheel is aimed straight ahead. Lock turntable. (Mazda)

ADJUSTING CASTER AND CAMBER

On many cars, adjusting caster will affect camber and vice versa. For this reason, caster and camber are usually adjusted and checked together.

There are a number of methods used to provide for caster and camber adjustment.

Shims may be used at both sides of the upper suspension arm inner ends, A, Fig. 32-11. An eccentric or a slot for the upper ball joint, coupled with an adjustable lower strut, may be used, B. Eccentric washers can be used at both sides of the upper arm inner ends, C. The upper arm inner end support shaft may be adjusted in or out by means of elongated holes, D. An adjustable strut and shims on the inner end of the lower arm may be used, E.

With shims on the inner ends of the upper shaft, caster can be altered by adding or removing shims from either end. If shims are as in Fig. 32-12 (shims between shaft and inner side of support frame), caster may be changed more positive by adding shims at A or by removing shims at B. Changing caster in a negative direction would require adding shims at B or removing shims at A.

When shims are used between the upper arm shaft and the OUTSIDE of the support frame, caster may be adjusted in a positive direction by removing shims at A or by adding shims at B. This will tip the outer end of the upper suspension arm toward the rear of the car. This will move the caster angle in a positive direction. Such an arrangement is shown in Fig. 32-13.

In cases where the upper arm shaft or support frame

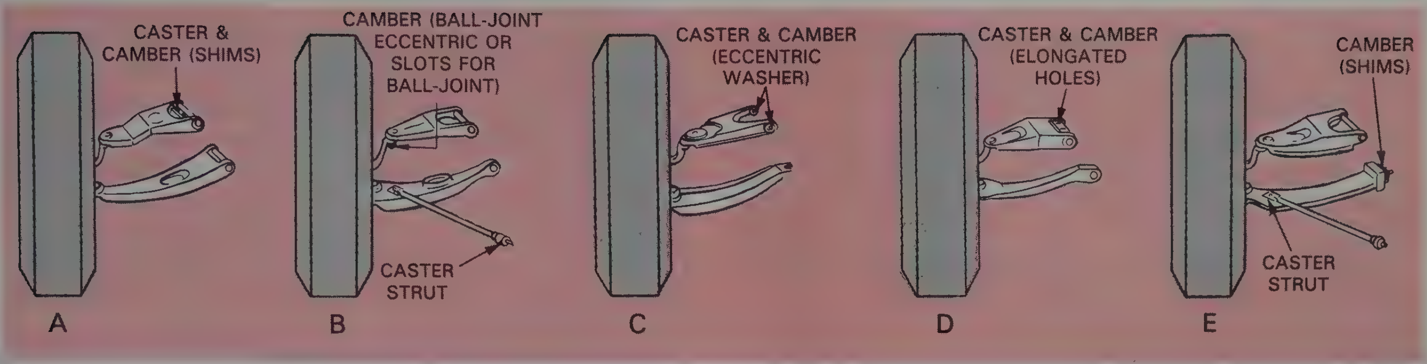

CASTER &
CAMBER (SHIMS)
CAMBER (BALL-JOINT ECCENTRIC OR SLOTS FOR BALL-JOINT)
CASTER STRUT
CASTER & CAMBER (ECCENTRIC WASHER)
CASTER & CAMBER (ELONGATED HOLES)
CAMBER (SHIMS)
CASTER STRUT
A
B
C
D
E

Fig. 32-11. Some of the methods employed to provide adjustment for caster and camber. (Hunter)

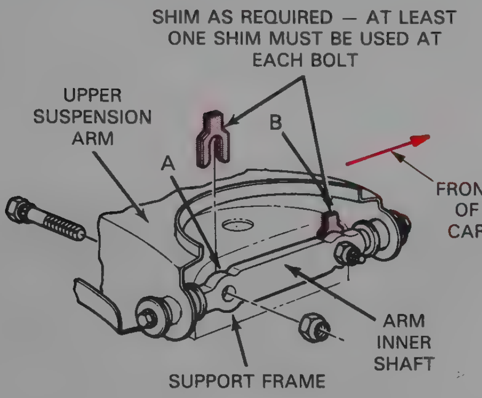

SHIM AS REQUIRED — AT LEAST ONE SHIM MUST BE USED AT EACH BOLT
UPPER SUSPENSION ARM
A
B
FRONT OF CAR
ARM INNER SHAFT
SUPPORT FRAME

Fig. 32-12. Caster and camber shims located between upper suspension arm inner shaft and inside of frame support. (Pontiac)

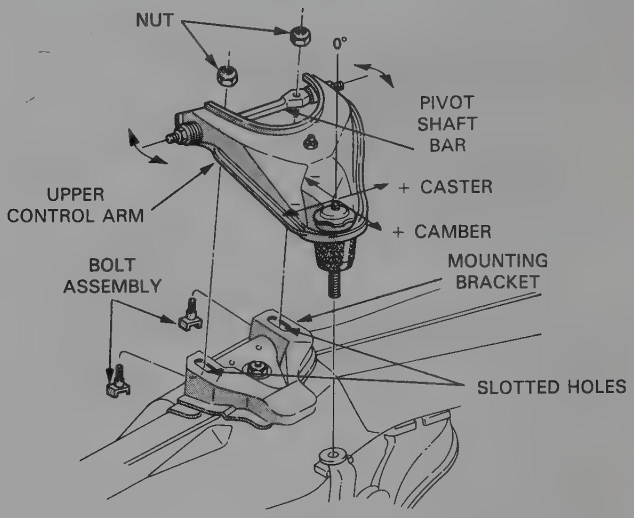

NUT
0°
PIVOT SHAFT BAR
UPPER CONTROL ARM
+ CASTER
+ CAMBER
BOLT ASSEMBLY
MOUNTING BRACKET
SLOTTED HOLES

Fig. 32-14. Upper pivot shaft (bar) can be adjusted by moving bolts in slotted holes. This will allow for proper caster and camber settings. (Dodge)

is slotted, moving either end in or out will change caster. Usually, the shaft and support frame are serrated (notched). By loosening the fasteners, the shaft may be shifted one or more serrations. Upon torquing the fastener, the shaft will be secured, Figs. 32-14 and 32-15.

Once caster is adjusted, camber may be altered by adding or removing an equal number of shims from both ends. This will cause the outer end of the suspension arm to move straight in or out without changing caster.

As illustrated in Fig. 32-11, other techniques are employed. Follow the manufacturer's instructions.

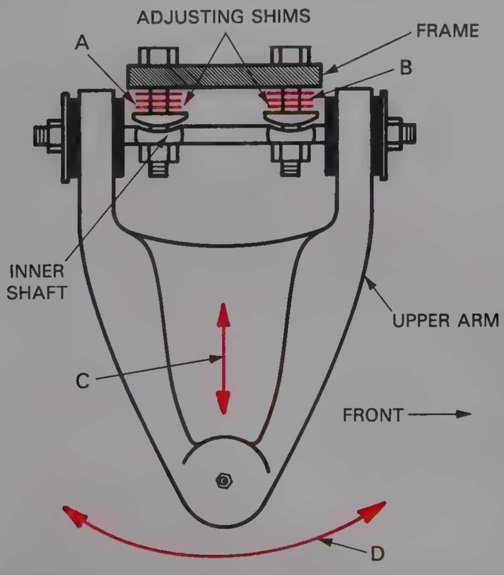

ADJUSTING SHIMS
A
FRAME
B
INNER SHAFT
UPPER ARM
C
FRONT
D

Fig. 32-13. Caster and camber shims (A and B) located between upper arm inner shaft and frame. By adding or subtracting shims, camber (C) or caster (D) angle can be changed. (Ammco)

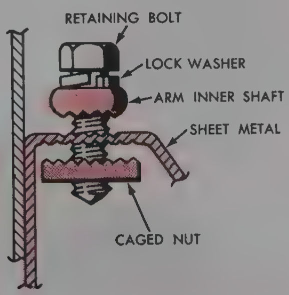

RETAINING BOLT
LOCK WASHER
ARM INNER SHAFT
SHEET METAL
CAGED NUT

Fig. 32-15. Serrations will hold suspension arm inner shaft in selected position when retaining bolt is torqued. (Ford)

Study of the suspension setup will usually indicate the correct procedure for camber and caster adjustments.

Caster may be adjusted on solid truck type front axles by placing tapered caster shims between the spring and axle, Fig. 32-16. Camber angles are built into some truck axles and can only be changed by bending the axle.

The "MacPherson" front suspension alignment is adjusted in a somewhat different manner than the conventional type. The following is a general alignment procedure. Be sure to follow vehicle maker's specifications and pre-alignment checks before continuing.

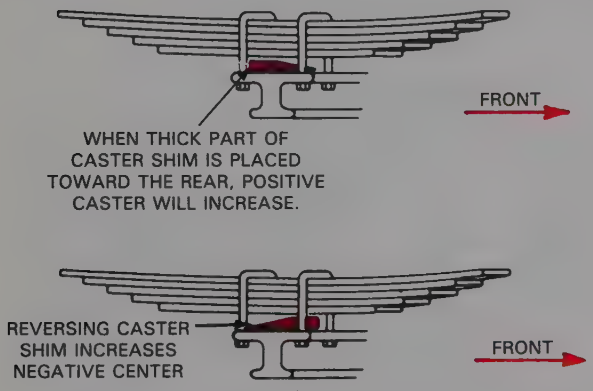

FRONT
WHEN THICK PART OF CASTER SHIM IS PLACED TOWARD THE REAR, POSITIVE CASTER WILL INCREASE.
REVERSING CASTER SHIM INCREASES NEGATIVE CENTER
FRONT

Fig. 32-16. Changing caster angle on solid axle, truck type front end. (Bear)

Mark and loosen cam and through-bolts on each side, Fig. 32-17. Turn the upper cam bolt to move top of wheel in (negative) or out (positive) to obtain proper camber setting.

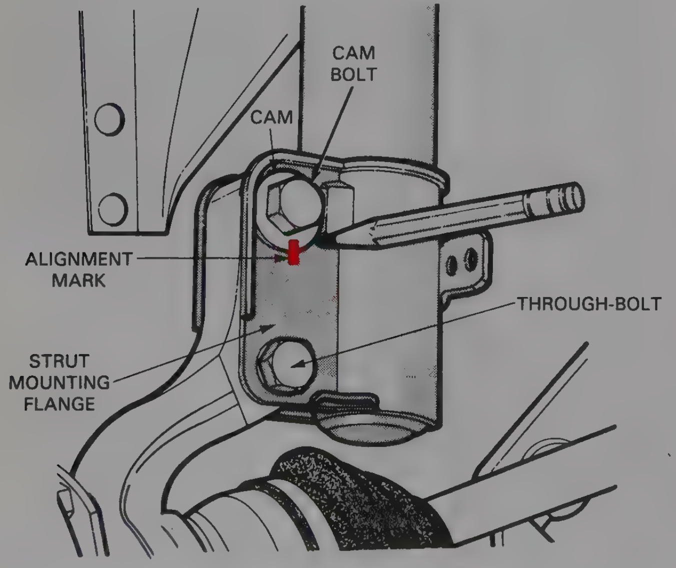

CAM BOLT
CAM
ALIGNMENT MARK
THROUGH-BOLT
STRUT MOUNTING FLANGE

Fig. 32-17. Place an alignment mark on cam and strut mounting flange to provide a reference point. (Chrysler)

Tighten cam and through-bolts to specified torque. Double-check for correct setting, Fig. 32-18.

Camber and toe are generally the only adjustments necessary with the MacPherson setup. If caster adjustment is required, follow manufacturer's recomendations.

Four-wheel drive vehicles can also have camber adjusted with camber shims, camber adjusting sleeves, or other means. Follow the vehicle manufacturer's recommendations and service procedures.

CAUTION! Never attempt any alignment adjustments by bending or heating parts unless specified by the maker. Suspension damage or failure is likely to occur.

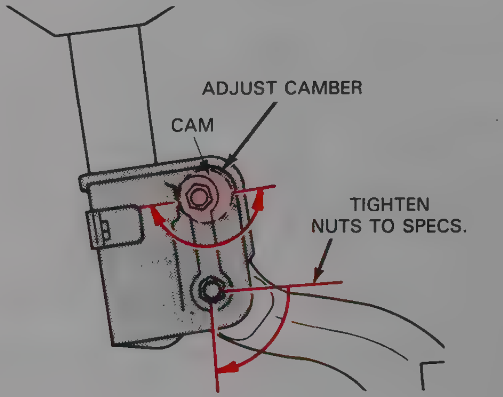

ADJUST CAMBER
CAM
TIGHTEN NUTS TO SPECS.

Fig. 32-18. As cam is adjusted, wheel will be tilted inward or outward at top. (Chrysler)

STEERING AXIS INCLINATION (SAI)

Steering axis inclination, sometimes referred to as kingpin inclination, is formed by tilting the top ball

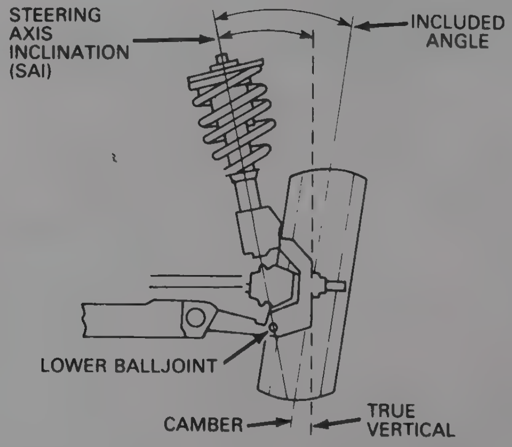

STEERING AXIS INCLINATION (SAI)
INCLUDED ANGLE
LOWER BALLJOINT
CAMBER
TRUE VERTICAL

Fig. 32-19. Steering axis inclination (SAI) is formed by tilting strut upper mount and lower ball joint as viewed from the front of the vehicle. This setting is normally negative on front-wheel drive vehicles. Note the included angle. This is the sum of the camber angle and the steering axis inclination. (GM)

joint or strut mount inward. This angle is measured in degrees from true vertical, Fig. 32-19.

Steering axis inclination places the load nearer the tire-road contact patch. This provides better tracking and easier steering.

Steering axis inclination is nonadjustable. If incorrect, check for a bent spindle, frame, strut, or other problem. Replace parts as needed.

The average steering axis inclination will run from around 4 to 9 deg. Use manufacturer's specifications.

When checking, make certain that the camber angle is taken into consideration in that a change in camber will also affect steering axis inclination. Keep the brake pedal applied while checking inclination. Use a pedal depressor, Fig. 32-20.

Camber, caster, and steering axis inclination are illustrated in Fig. 32-21.

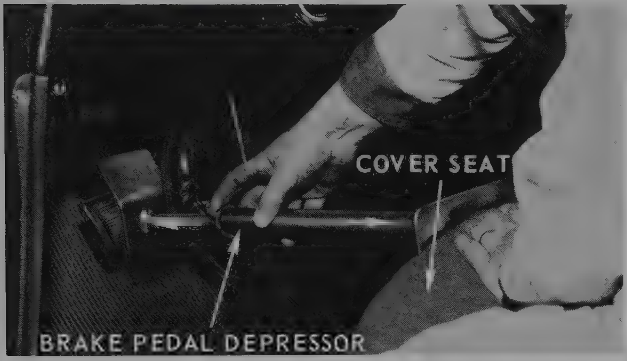

COVER SEAT
BRAKE PEDAL DEPRESSOR

Fig. 32-20. Use a brake pedal depressor when checking steering axis inclination. Protect seat surface. (Ammco)

TOE-IN

Toe-in is a condition in which the front of the tires are closer together than the back. Look at Fig. 32-22.

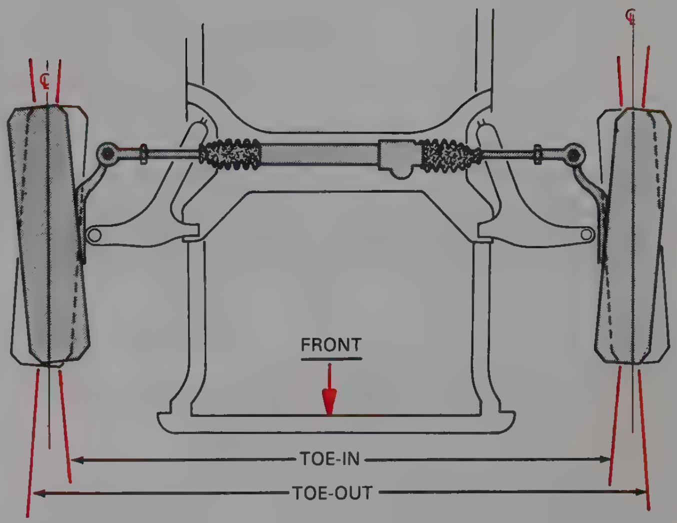

℄
℄
FRONT
TOE-IN
TOE-OUT

Fig. 32-22. Toe-in and toe-out. Note that wheels are closer together at front than back with toe-in. (Chrysler)

Note that distance at the back of the tires is greater than distance in the front.

Toe-in is used to compensate for the natural tendency of the road-to-tire friction to force the wheels apart. On some front-wheel drive cars, however, the front tires are toed-out (negative toe). This is done to offset the force created by the drive axles, which tends to drive or throw the tires inward during operation. The toe-out setting compensates for this and allows the front tires to run parallel to one another while rolling straight down the road.

CHECKING TOE-IN

Various devices may be used for checking toe-in. A quick check is provided with the equipment pictured in Fig. 32-23. As the car is driven across the base, the machine indicates toe-in or toe-out.

Other devices employ light beams or optical devices.

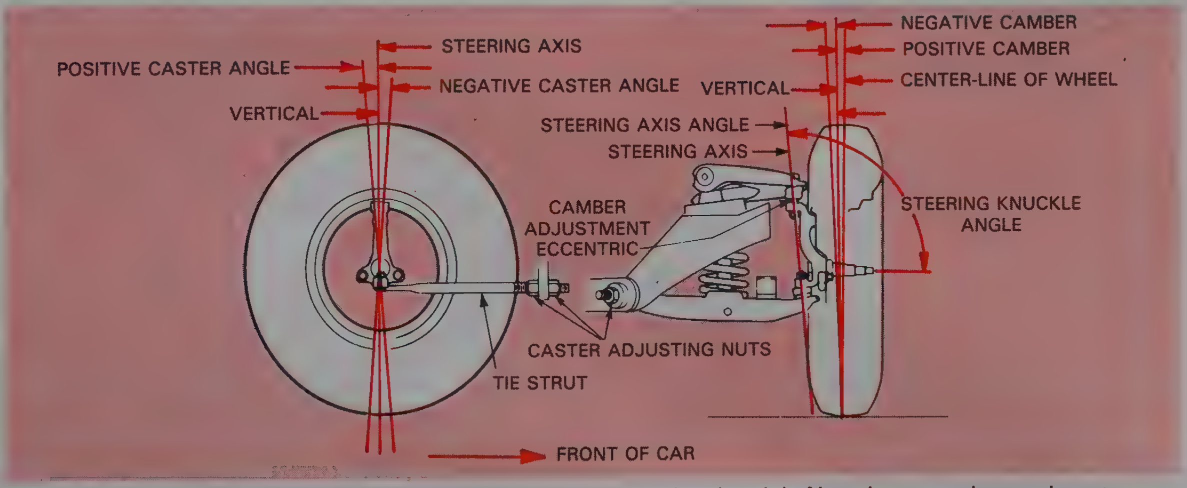

POSITIVE CASTER ANGLE
STEERING AXIS
NEGATIVE CASTER ANGLE
VERTICAL
NEGATIVE CAMBER
POSITIVE CAMBER
CENTER-LINE OF WHEEL
VERTICAL
STEERING AXIS ANGLE
STEERING AXIS
STEERING KNUCKLE ANGLE
CAMBER ADJUSTMENT ECCENTRIC
CASTER ADJUSTING NUTS
TIE STRUT
FRONT OF CAR

Fig. 32-21. Camber, caster, and steering axis inclination (angle). Note how camber and caster are adjusted on this setup. (Cadillac)

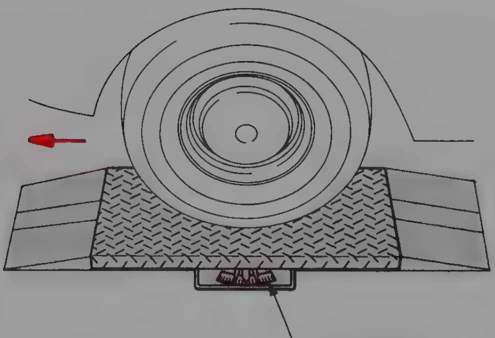


Fig. 32-23. Vehicle being driven over one particular toe-in indicator setup. (Toyota)

One of the simplest tools is the toe gauge or trammel.

To check the toe-in with a trammel, jack up each front wheel and chalk a heavy band near the center of the tire while spinning the wheel. Refer to Fig. 32-24.

Use a sharp nose scriber to form a thin line near the center of the chalk band while spinning the wheel. Keep the line THIN. Lower wheels to floor. Roll car forward until wheels have made one complete turn. Wheels should point straight ahead. This will impart a rearward thrust to the wheels and will provide an accurate toe-in reading.

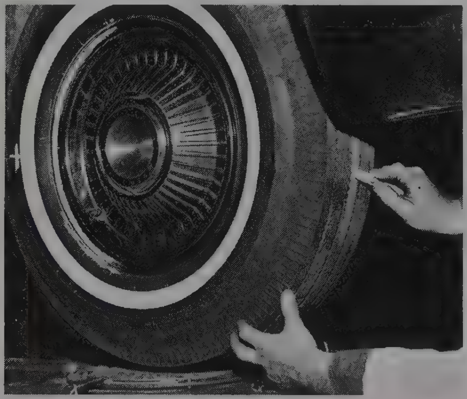


Fig. 32-24. While spinning the wheel, chalk a heavy band near the center of the tire.

Move the trammel in back of the wheels. Set the pointers exactly on the scribed lines. The top of the pointers should be as near to the center of the spindle height as possible.

Carefully remove the trammel without altering the height or setting of the pointers. Align one pointer with a scribe mark on the front of the tires. Check the distance between the other pointer and scribe mark. The distance will indicate the amount of toe-in or toe-out present. See Fig. 32-25.

TOE-IN IS CRITICAL. An improper setting can grind off the tire tread in a very short period of driving.

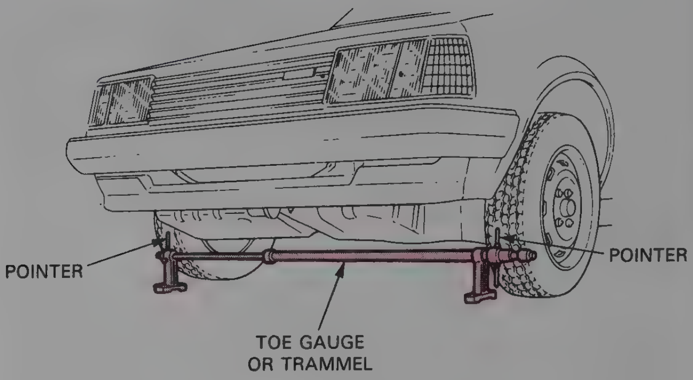


Fig. 32-25. Checking toe with a trammel. (Mazda)

ADJUSTING TOE-IN AND STEERING WHEEL POSITION (CENTER POINT STEERING)

The steering wheel should be mounted on the steering shaft so that when the steering gear is on the center point of its travel, the steering wheel spokes will be in a horizontal position (two spoke wheel) or the center spoke (three spoke wheel) will be facing downward.

Some steering wheel hubs and shafts are marked or are keyed for proper alignment. If they are not, and the steering wheel is off-center, center the wheel.

Turn the steering wheel to the left as far as it will go. Place a chalk mark at the very top. Slowly turn the wheel to the extreme right while counting the number of turns required. Now turn the wheel back in the left-hand direction exactly one-half of the total number of turns required from extreme left to right. The spokes should be in the desired position. If they are not, pull the steering wheel and replace in the correct position. DO NOT MOVE THE STEERING SHAFT DURING THIS OPERATION, Fig. 32-26.

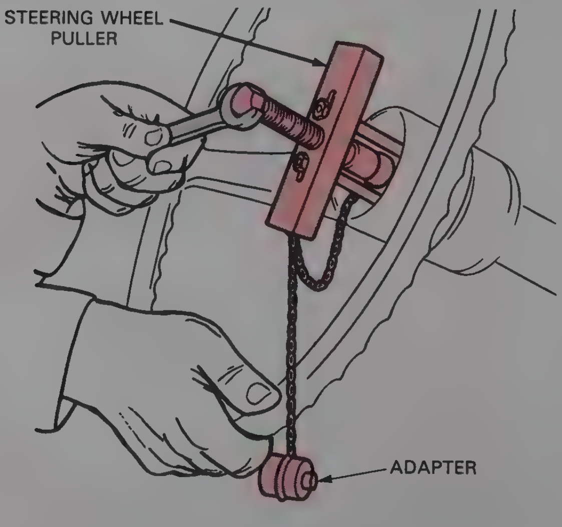


Fig. 32-26. Removing steering wheel with a puller. Note adapter which allows puller to fit other steering wheel hub designs. (GMC)

When replacing the steering wheel, install the key (when used) and any locking device. If hub and shaft are marked, align marks. Torque retaining nut and coat the exposed shaft threads with a special locking compound to prevent the nut from loosening. If locking compound is not used, stake the nut with a sharp punch. Make certain the wheel is on tight and that it will remain tight.

Turn the wheel again from extreme left to right and back to the left exactly one-half the number of turns. The steering wheel spokes should now be in the correct position.

Adjust the toe-in by turning the tie rod adjusting sleeves in the required directions. Look at Fig. 32-27.

DANGER: ON SOME CARS, THE TIE ROD ADJUSTING SLEEVE CLAMP BOLTS MUST BE IN A SPECIFIC LOCATION IN RELATION TO THE TIE ROD TOP OR FRONT SURFACE TO PREVENT INTERFERENCE WITH OTHER PARTS.

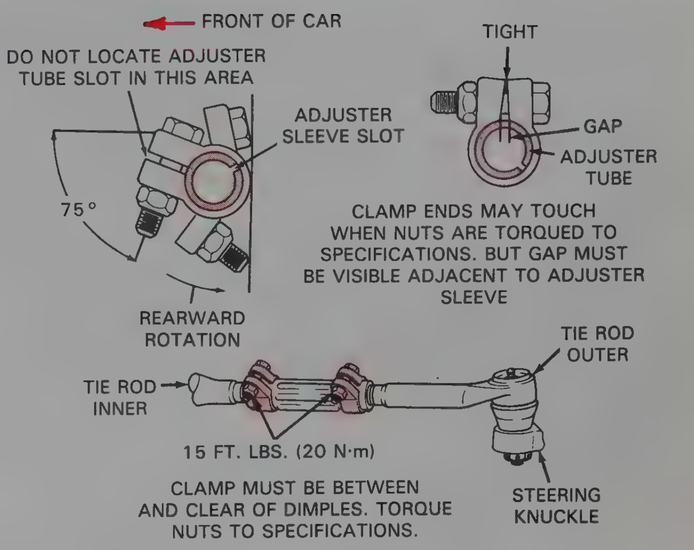

FRONT OF CAR
DO NOT LOCATE ADJUSTER TUBE SLOT IN THIS AREA
TIGHT
ADJUSTER SLEEVE SLOT
GAP
ADJUSTER TUBE
75°
CLAMP ENDS MAY TOUCH WHEN NUTS ARE TORQUED TO SPECIFICATIONS. BUT GAP MUST BE VISIBLE ADJACENT TO ADJUSTER SLEEVE
REARWARD ROTATION
TIE ROD OUTER
TIE ROD INNER
15 FT. LBS. (20 N·m)
CLAMP MUST BE BETWEEN AND CLEAR OF DIMPLES. TORQUE NUTS TO SPECIFICATIONS.
STEERING KNUCKLE

Fig. 32-28. Proper positioning of one particular tie rod adjusting sleeve clamp. (Oldsmobile)

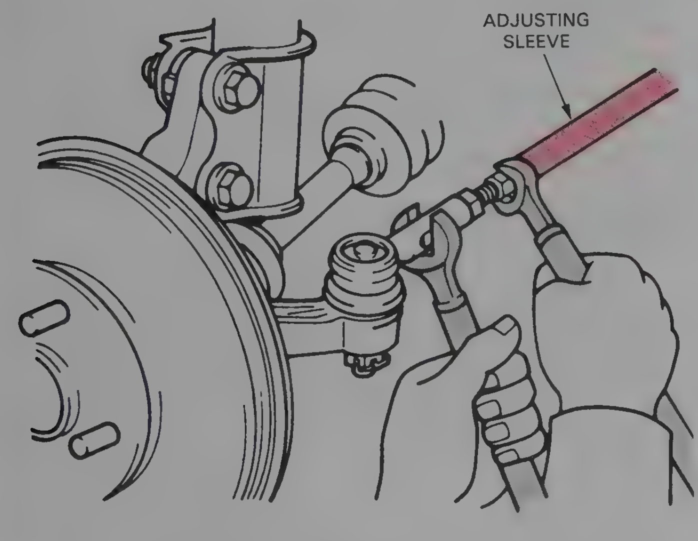

ADJUSTING SLEEVE

Fig. 32-27. Adjusting front toe-in. Turn adjusting sleeve as specified in service manual. (Geo)

Follow the manufacturer's recommendations for proper clamp positioning. If none are available, study the setup and be certain no interference is possible. Fig. 32-28 illustrates the proper positioning for one particular setup.

Sleeve clamps must be over the threaded rods and must be torqued. The sleeve should be centered over the tie rod and tie rod socket shaft.

REMEMBER, A LOOSE TIE ROD SLEEVE, AN IMPROPERLY POSITIONED CLAMP, A LOOSE FASTENER, OR A POORLY CENTERED SLEEVE CAN CAUSE A TRAGIC ACCIDENT. BE CAREFUL.

When the toe-in is adjusted correctly, wheels in the straight ahead position, the steering wheel spokes must be properly aligned. If they are not, the wheel may be centered by turning both tie rod sleeves in the same direction until wheel is aligned. Some cars have only one sleeve.

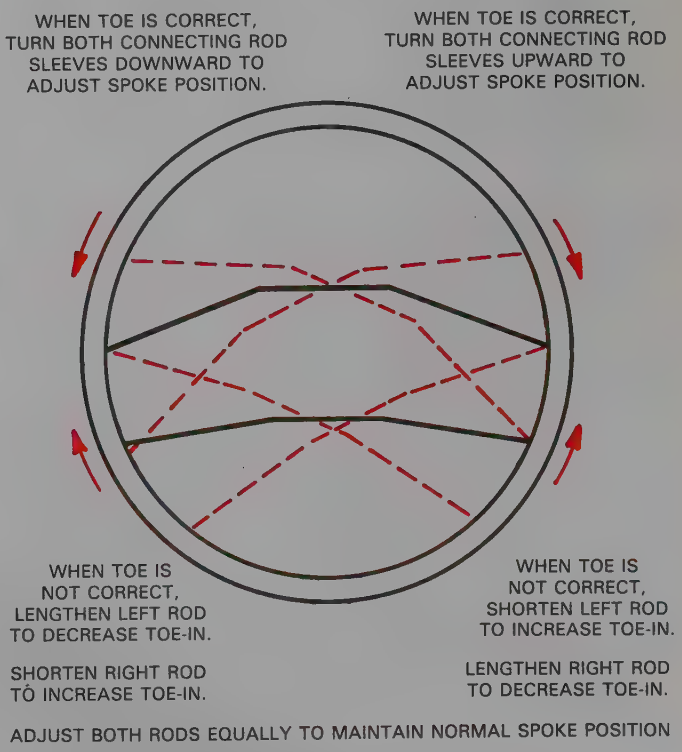

WHEN TOE IS CORRECT, TURN BOTH CONNECTING ROD SLEEVES DOWNWARD TO ADJUST SPOKE POSITION.
WHEN TOE IS CORRECT, TURN BOTH CONNECTING ROD SLEEVES UPWARD TO ADJUST SPOKE POSITION.
WHEN TOE IS NOT CORRECT, LENGTHEN LEFT ROD TO DECREASE TOE-IN.
SHORTEN RIGHT ROD TO INCREASE TOE-IN.
WHEN TOE IS NOT CORRECT, SHORTEN LEFT ROD TO INCREASE TOE-IN.
LENGTHEN RIGHT ROD TO DECREASE TOE-IN.
ADJUST BOTH RODS EQUALLY TO MAINTAIN NORMAL SPOKE POSITION

Fig. 32-29. Correcting steering wheel spoke positioning by adjusting tie rod sleeves. Bolts must be installed in direction shown. Rotate both inner and outer tie rod housings rearward to limit of ball joint travel before tightening clamps. With this same rearward rotation, all bolt centerlines must be between angles shown after tightening clamps. (Ford)

Wheel spoke positioning for one car is shown in Fig. 32-29. Study the directions. Note that by turning both sleeves the same direction, the spokes can be moved without changing toe-in. When toe-in is incorrect, one sleeve is moved in one direction and the other in the opposite direction to move the spokes and to correct the toe-in.

When finished, steering wheel should be in the correct plane with front wheels in straight ahead position. Both front wheels should be at same angle to a centerline drawn through the car in a lengthwise direction, and with steering gear on the center point of travel. Look at Fig. 32-30.

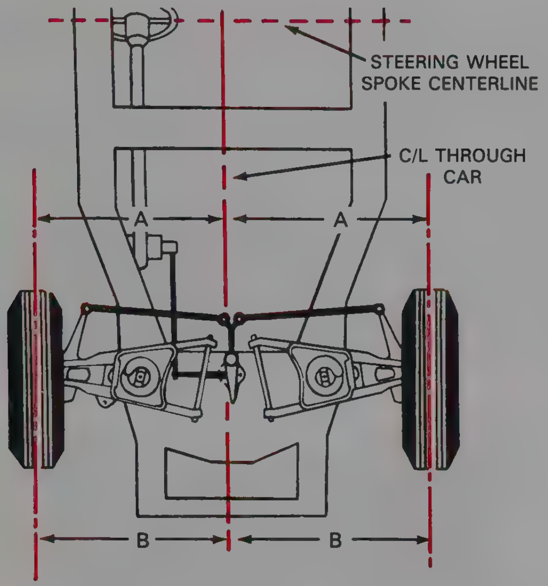


Fig. 32-30. Center point steering. Steering wheel (two spoke) in correct plane, wheels forming equal angles to centerline (C/L) with wheels in straight ahead position. Both A dimensions are equal as are both B dimensions.

TOE-OUT ON TURNS (TURNING RADIUS)

When the car rounds a corner, the front wheel on the inside of the turn is forced to follow a smaller arc than the outer wheel. If the wheels remained parallel during the turn, the tires would be forced to slip.

Note that the steering arms in A, Fig. 32-31, are parallel to the centerline of the car. With such an arrangement, when making a turn, the front wheels remain parallel. This causes tire slip, B.

Tire slip on turns is avoided by angling the steering arms in a manner similar to that pictured in A, Fig. 32-32. When the front wheels are turned, the inner wheel will be forced to turn more sharply. This allows all wheels to turn from the same center, thus eliminating tire slip. In effect, the front wheels during turns, actually toe-out a small amount, B, Fig. 32-32.

The angle of toe-out on turns is usually specified in

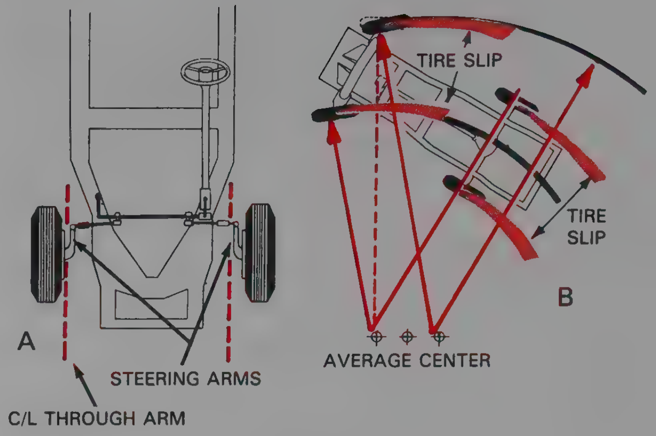


Fig. 32-31. When steering arms are parallel (red lines) as in A, front wheels remain parallel during turns, thus causing tire slip, B. (Hunter)

one of two ways. Specifications may call for the outer wheel to be at a certain angle when the inner wheel is turned to exactly 20 deg. They may also specify a certain angle for the inner wheel when the outer wheel is turned to 20 deg.

Although specs vary, they usually call for around a 1 to 3 deg. difference between the inner and outer wheel turning angles. See Fig. 32-33.

CHECKING TOE-OUT ON TURNS

Lock brakes with pedal depressor. Turntables must be set at 0 deg. with locking pins removed. Wheels should be in the straight ahead position.

Turn the front of the right wheel inward until turntable dial reads exactly 20 deg. Read the indicator on the left wheel. This reading is the angle of toe-out for

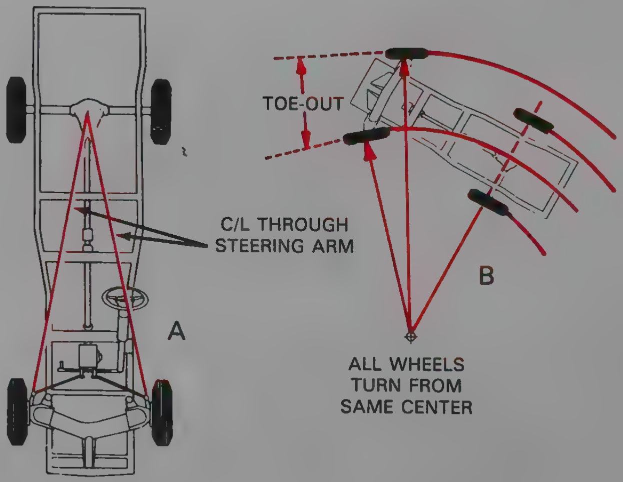


Fig. 32-32. A—Angling steering arms causes toe-out to occur on turns. B—This allows tires to roll about their respective arcs without slipping.

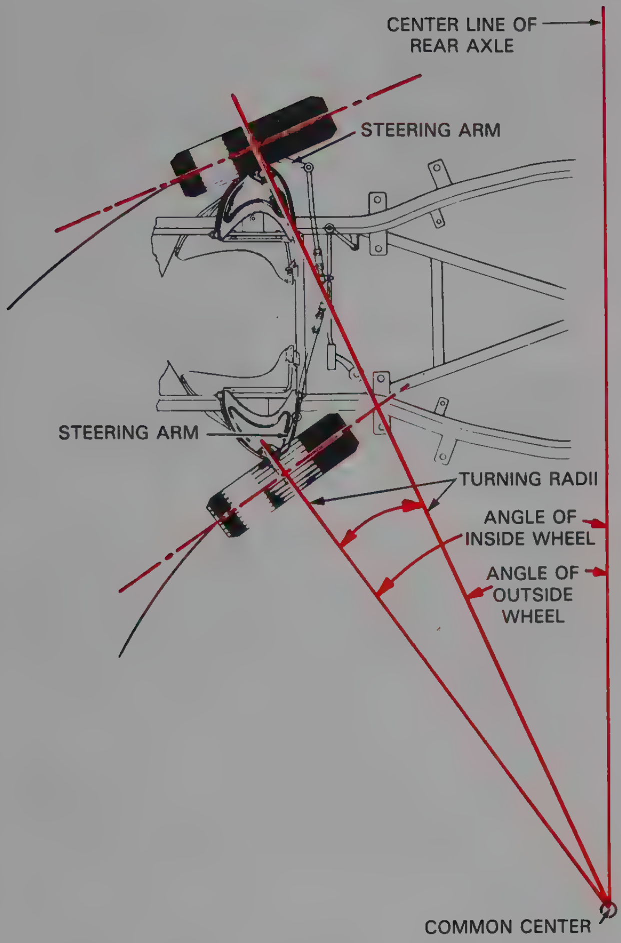


Fig. 32-33. Toe-out on turns must be as specified. Wheels turn about a common center determined by wheelbase of vehicle. Note that with respect to common point, inside wheel is ahead of outside wheel and makes a sharper angle than outer one. (Bear)

the LEFT WHEEL. It should be slightly more than 20 deg.

Turn the front of the left wheel inward 20 deg. and then read indicator on the right wheel turntable. This is the angle of toe-out for the RIGHT WHEEL. Compare with specifications.

Turning radius or angle of toe-out is built into the steering arms. If the angles are not according to specifications, the steering arms are bent. Replace bent arms. Fig. 32-34 illustrates the use of a turntable in checking turning radius.

Fig. 32-35 illustrates a vehicle set up to be checked for toe-out on turns with a special optical alignment machine. A beam of light is projected from the wheel mounted unit to the chart in front of the vehicle.

WHEEL TRACKING—THRUST ANGLES

Tracking is the ability of a vehicle's rear wheels to follow directly behind the front wheels. If the rear wheels are not tracking correctly, the vehicle will not travel in a straight line unless the front wheels are turned to compensate for the misalignment. This condition is often referred to as "dog tracking," Fig. 32-36.

Tracking is set by aligning the vehicle's thrust angle with its geometric centerline, Fig. 32-37. Ideally, the thrust angle should cover the centerline. This would result in perfect tracking. Manufacturer's tolerances, accidental damage, and normal wear, however, make perfect alignment rare. Front-wheel drive, all-wheel drive, and four-wheel steering also complicate thrust

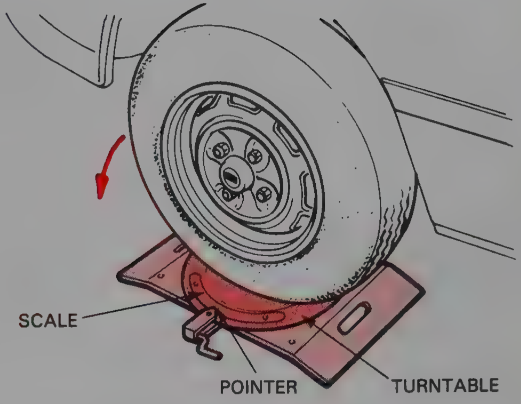


Fig. 32-34. Turning radius is being checked by placing vehicle on turntable. Reading is obtained with scale and pointer. (Mazda)

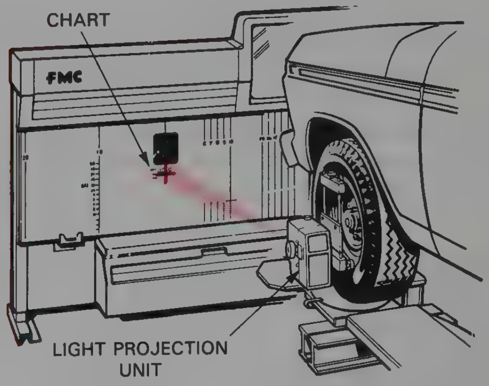


Fig. 32-35. Vehicle set up to have toe-out on turns checked. As wheel is turned, light beam cross will move on chart. (FMC)

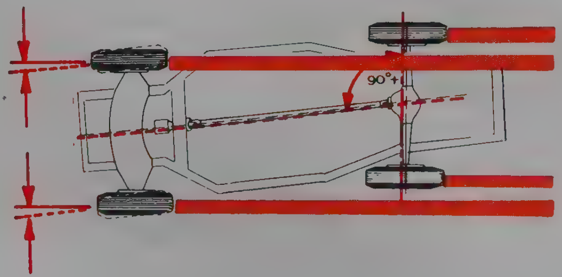


Fig. 32-36. Dog tracking occurs when the rear wheels do not follow directly behind the front wheels. (Hunter)

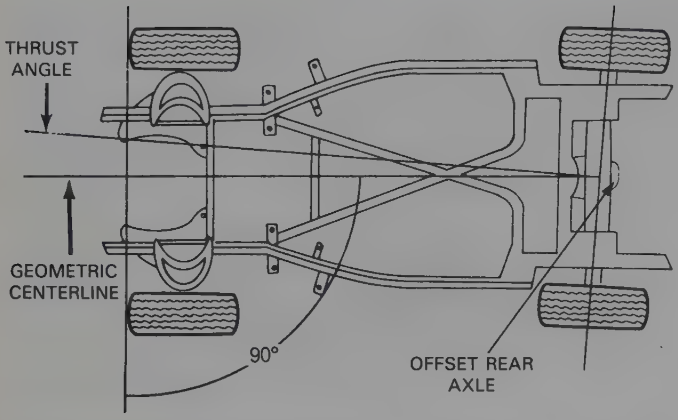

THRUST ANGLE
GEOMETRIC CENTERLINE
90°
OFFSET REAR AXLE

Fig. 32-37. Relationship between vehicle's thrust angle and centerline. Note that rear axle is offset and angle is greater than 90°. (Sun Electric)

angle alignment. The technician must strive to align the thrust angle and the geometric centerline as closely as possible.

Thrust angles should always be checked and adjusted according to manufacturer's instructions. Tire scrubbing, poor fuel economy, and incorrect handling can result if the alignment is not properly set.

Fig. 32-38 illustrates one method of measuring rear wheel track. This equipment uses a laser light beam to accurately check the settings.

ALIGNMENT JOB MUST BE THOROUGH

In addition to the prealignment inspection, make certain that vehicle curb height is as specified, A, Fig. 32-39. Check that caster, B, and camber, C, are correct. Check that the proper toe-in, D, exists. Check that the steering axis inclination is as required, E, and that toe-out on turns meets specifications, F.

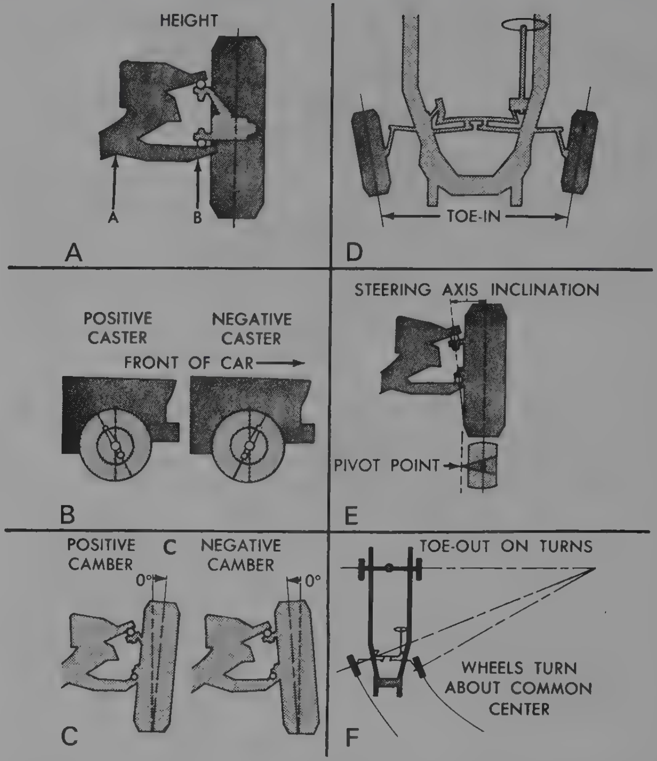

HEIGHT
A
B
A
TOE-IN
D
POSITIVE CASTER
NEGATIVE CASTER
FRONT OF CAR
B
STEERING AXIS INCLINATION
PIVOT POINT
E
POSITIVE CAMBER
C
NEGATIVE CAMBER
0°
0°
C
TOE-OUT ON TURNS
WHEELS TURN ABOUT COMMON CENTER
F

Fig. 32-39. To insure proper steering and handling characteristics, all of these wheel alignment factors must be as specified. (Plymouth)

SETBACK

Setback is a condition in which one front wheel spindle is positioned behind the spindle on the opposite side. This condition can also be present in rear wheel assemblies. One indication of setback is a caster reading that varies by more than one degree from one side of the vehicle to the other.

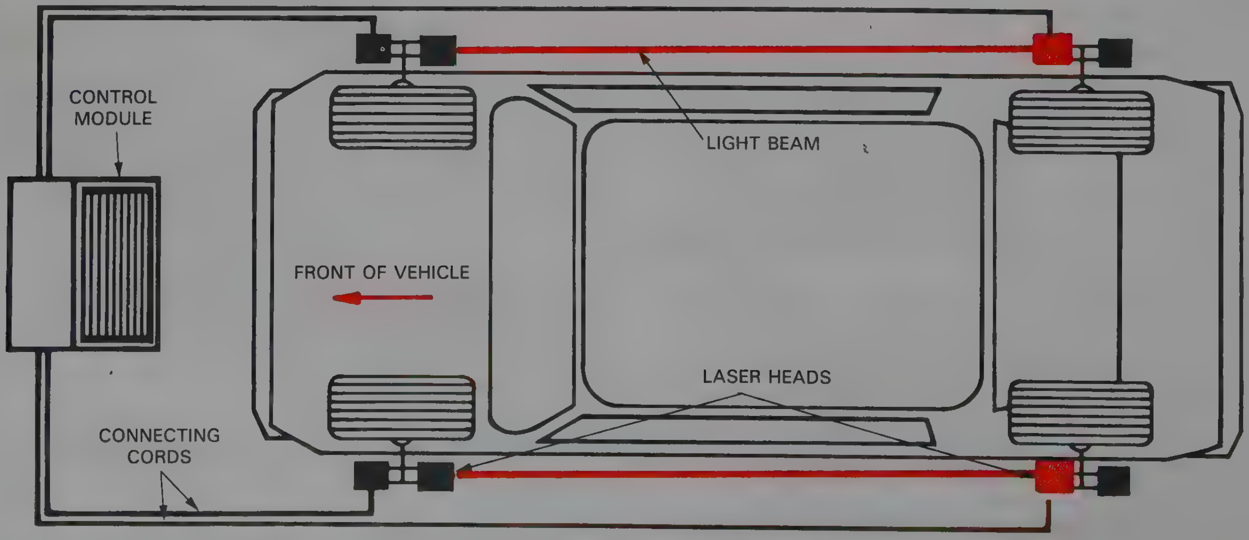

CONTROL MODULE
LIGHT BEAM
FRONT OF VEHICLE
LASER HEADS
CONNECTING CORDS

Fig. 32-38. Vehicle set up to have rear wheel track checked with a helium-neon laser machine. A precise reading can be obtained using this type of equipment. (Chief)

WHEEL ALIGNMENT IS A PRECISION JOB

Use quality aligning equipment, in proper condition. Employ correct techniques. Make all checks and adjustments carefully and to exact specifications. Precision steering and handling require precision alignment. Never use heat on suspension or spindle parts. Avoid bending parts. If parts must be bent, always cold bend and then never more than 5 deg.

ALWAYS ROAD TEST

It is good practice to road test the car both BEFORE and AFTER wheel alignment.

FRONT WHEEL BEARINGS

Front wheel bearings are of two types: ball and tapered roller. Current practice favors the use of the tapered roller. Refer to Fig. 32-40.

A front wheel, hub, and bearing setup is illustrated in Fig. 32-41.

FRONT WHEEL REMOVAL—REAR WHEEL DRIVE

Pry off the wheel cover, being careful to avoid springing it out of shape. Pry a little at a time, moving around the cap.

Remove the bearing dust cap. Straighten cotter pin and remove. Unscrew the adjusting nut (some cars use a left-hand thread on the driver's side). Remove the pronged safety thrust washer. Shake the wheel from side to side, or pull the wheel outward a short distance. Then push it back on. This will move the outer bearing from the hub. Remove outer bearing and place in a clean container.

Grasp tire firmly and pull wheel straight off the spindle. Support tire and wheel assembly so that the inner bearing and seal are not dragged across the spindle threads. See Fig. 32-42.

Some mechanics prefer to pull the tire and wheel assembly from the hub and then remove locknut and pull the hub by itself. This is required with front disc brakes in order to remove the caliper. When removing caliper, do not disconnect the brake line.

If the brake shoes drag and make wheel assembly removal difficult, back off the brake shoe adjustment (see chapter on brake service).

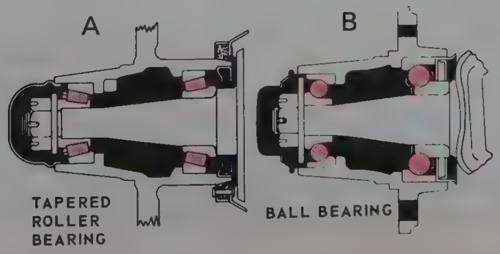


Fig. 32-40. Front wheel bearings. A—Tapered roller. B—Ball.

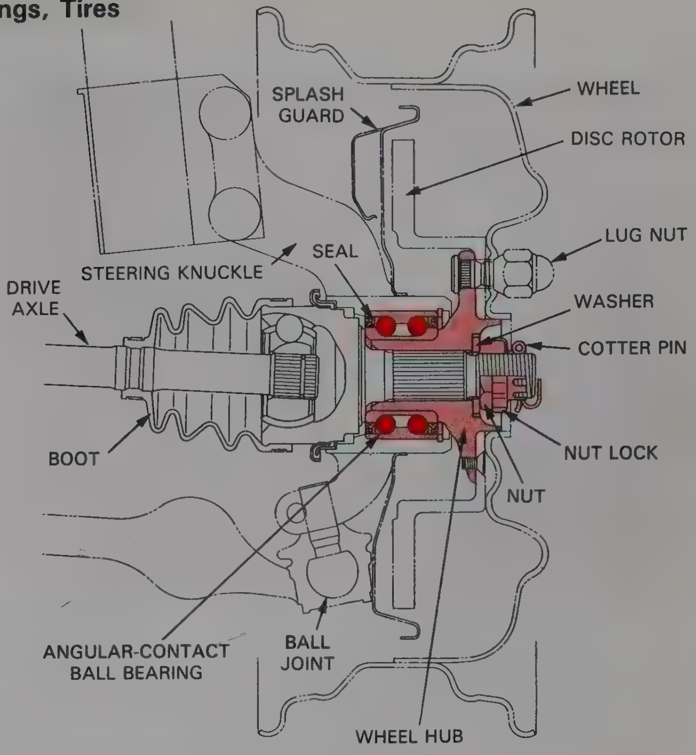


Fig. 32-41. One type of front-wheel drive hub and bearing assembly. Proper bearing preload can be obtained by torquing the drive axle (shaft) nut to specifications. (Daihatshi)

FRONT WHEEL REMOVAL—FRONT-WHEEL DRIVE

The following removal procedure covers general steps. Follow maker's disassembly recommendations for the particular vehicle at hand.

Begin by taking off the hub cap or wheel cover. Remove the cotter pin, nut lock (when used), hub nut, and safety washer. Replace nut if it is the staked type. Always discard the cotter pin.

Unbolt and remove brake caliper. Support it with a wire hook. Never support caliper with the brake hose. Remove brake rotor.

Loosen and remove hub mounting bolts and splash shield. If bearing is going to be reused, mark mounting flange and knuckle so it can be reassembled in the correct position. An exploded view of hub components is shown in Fig. 32-43.

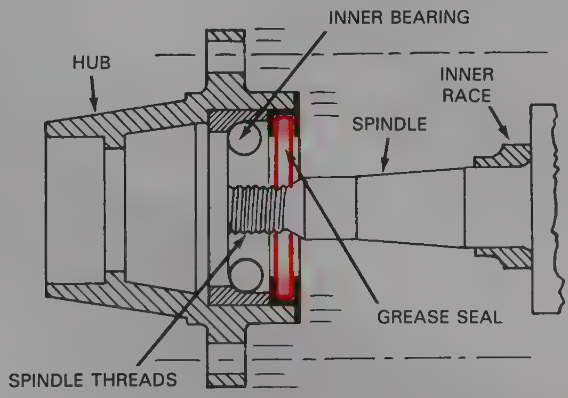


Fig. 32-42. Support wheel when removing or installing to prevent inner bearing and grease seal from dragging over spindle threads.

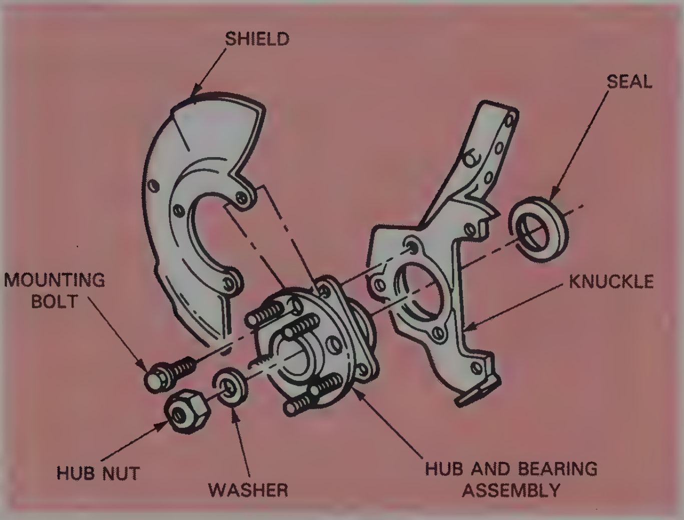


Fig. 32-43. Exploded view of one type of wheel hub and bearing assembly. (Pontiac)

Some vehicles require that a puller be attached to draw the hub and bearing unit from the drive axle. DO NOT use a hammer or heat to aid removal. See Fig. 32-44.

INNER WHEEL BEARING AND SEAL REMOVAL

Lay the wheel over a clean rag or piece of paper. Use a long, soft steel drift and engage the inner bearing cone. Do not engage roller cage.

Tap inner bearing from the hub. Tap a little at a time. Move the drift around the cone. This will remove the bearing and grease seal.

In the case of ball bearings, try to remove the grease seal by using an offset tip drift that will engage the grease seal. This will avoid driving against the ball cage. A special seal puller may also be employed.

Discard the grease seal. Always use a new grease seal following bearing or brake service.

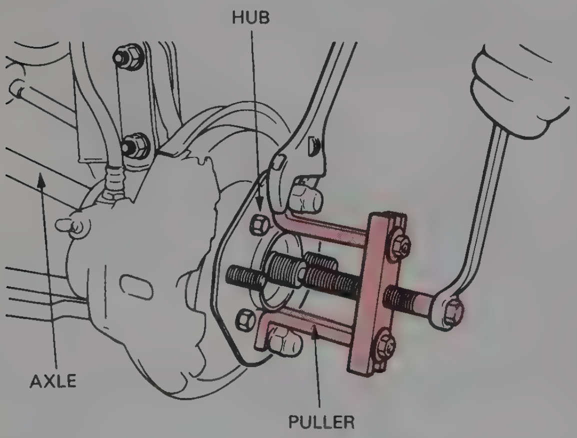


Fig. 32-44. Using puller to remove hub. Do not use heat. (Dodge)

CLEAN AND EXAMINE BEARINGS

See chapter on antifriction bearings for complete instructions on bearing cleaning and checking.

Important points to remember are: Use a final rinse of CLEAN solvent. Never spin the bearing with air pressure. Examine each roller, ball, cup, and cone. Pack bearings with lubricant and store in clean container until ready to use. Discard bearings showing the slightest signs of chipping, galling, or wear. If the balls are damaged, also replace both inner and outer race. If the cone and roller assembly is defective, replace cup also. A used cone and roller assembly must always be installed in the original cup. Ball and cage assembly must always be installed in the same inner and outer races.

REMOVING AND INSTALLING HUB BEARING CUPS

Thoroughly clean and flush out inside of hub. DO NOT ALLOW SOLVENT AND GREASE TO CONTACT BRAKE DRUM OR DISC SURFACE. Wipe dry with clean cloth. Inspect bearing cups. If damaged, or if either inner or outer roller and cone assembly is damaged, remove the corresponding cup, Fig. 32-45.

Use a brass or soft steel drift. If the hub is slotted, catch the exposed edge of the cup (race) at the slot. If slots are not provided, engage the thin exposed cup edge.

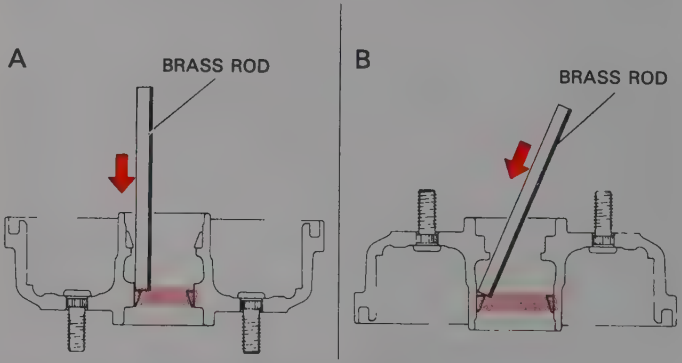


Fig. 32-45. A—Driving outer bearing cup (race) from hub. B—Driving inner cup from hub. (Mitsubishi)

Tap the cup from the hub. Move the drift around so that the cup is forced out without excessive tipping. Tipping the cup can distort the hub. Use care to avoid damaging the hub with the drift.

A puller, as in Fig. 32-46, will remove the hub cups easily and will avoid tipping.

Wipe hub recess clean. Lubricate new bearing cup and place in position over recess. MAKE CERTAIN CUP FACES IN THE CORRECT DIRECTION. Using a cup driver, drive the cup inward until seated firmly against stop. Refer to Fig. 32-47.

The cup may be pressed into place if such equipment

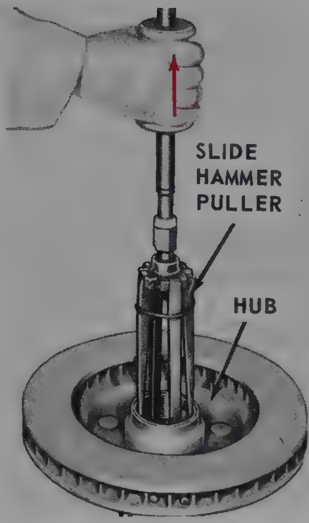


Fig. 32-46. Using a slide hammer puller to remove hub bearing cup. (Lincoln)

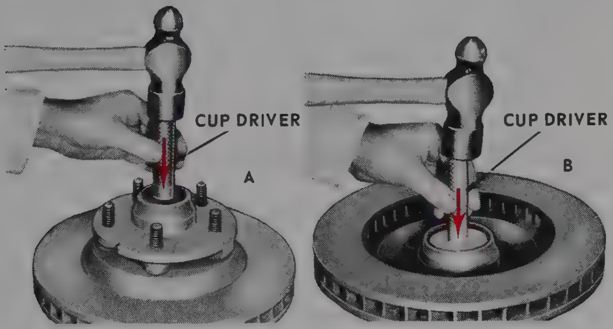


Fig. 32-47. A—Installing outer cup. B—Installing inner bearing cup. Note use of cup driver.

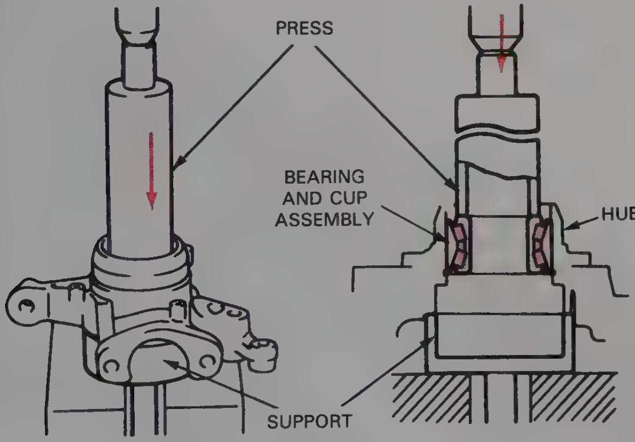


Fig. 32-48. Using a press to install bearing and cup assembly into hub. Wear safety glasses! (Toyota)

is available. See Fig. 32-48.

If a drift punch is used, tap a little at a time. Move the punch around the cup to avoid cocking or tipping. Use a soft steel drift. Never use a hardened punch.

WHEEL BEARINGS MUST BE PACKED WITH GREASE

Using a bearing packer, or your hands, pack each bearing FULL of the specified wheel bearing grease. (See chapter on antifriction bearings.)

NEVER MIX WHEEL BEARING GREASES OR ADD GREASE TO A BEARING WITHOUT FIRST REMOVING ALL ORIGINAL GREASE FROM BOTH BEARINGS AND HUB. GENERALLY, SHORT FIBER WHEEL BEARING GREASES CONTAIN EITHER LITHIUM OR SODIUM SOAPS. THE TWO TYPES OF GREASE ARE NOT COMPATIBLE. THEY SHOULD NEVER BE MIXED. USE ONLY HIGH TEMPERATURE GREASE ON A VEHICLE EQUIPPED WITH DISC BRAKES.

Make sure each bearing is fully packed and that a generous amount of grease is applied to the outside of the rollers or balls. Never apply grease to an oily bearing as the grease will not adhere properly. Bearing must be clean and dry before packing.

APPLY GREASE TO HUB AND DUST CAP

To prevent rust from moisture condensation and grease runoff from the bearings, both the hub and dust cap interior should be given a coating of grease. The coating in the cap can be relatively light. Coat the hub inner cavity to a depth that will bring the grease level up to the inner edge of the bearing cups. Never pack the hub full of grease. Pack as illustrated in Fig. 32-49. Coat cup surfaces.

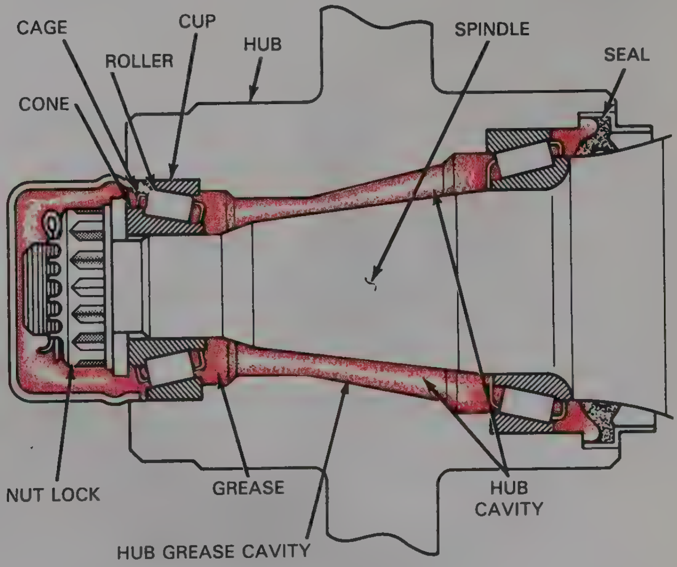


Fig. 32-49. Fill hub grease cavity to approximate depth shown. Place a light film inside dust cap also. Follow vehicle maker's recommendations for type and amount of grease. (Plymouth)

CLEAN BRAKE ASSEMBLY AND SPINDLE

Cover the spindle with a clean cloth. Clean off brake assembly with approved equipment. Do not apply a direct blast of cleaning fluid, as the dust and dirt could be forced into the wheel cylinders and calipers. See asbestos warning in Chapter 31.

Clean the spindle thoroughly with a cloth dampened with solvent. Wipe dry with a CLEAN cloth.

Examine the spindle carefully for signs of cracking, wear, or scoring. If the car has considerable mileage or is used in heavy service, it is good practice to apply a crack detecting solution to the spindle.

The roller cones are designed to "creep" or "walk" around on the spindle. This creeping action presents a constantly changing portion of the cone to the heaviest pressure from the rollers. This increases bearing life.

To insure proper cone creeping, the inside of the cone and the area of the spindle engaged by the cone must be very smooth and coated with a film of grease. If rusty or at all rough, polish the cone contact areas of the spindle with crocus cloth. Wipe clean.

Lubricate the entire spindle with a light coat of wheel bearing grease to prevent rusting and to facilitate cone creeping action.

INSTALL A NEW GREASE SEAL

Insert the packed inner roller and cone assembly into the hub. If the new grease seal is of the leather or felt type, it should be soaked in engine oil for 20 to 30 minutes. If of the neoprene type, lubricate the seal lip with a light wipe of wheel bearing grease.

Wipe off the outer edge of the seal and apply a LIGHT coat of nonhardening sealer. Wipe out seal recess in hub and place seal, lip facing inward, on the hub. Using a seal driver, drive seal to proper depth. Do not drive in so deeply that seal engages bearing. Seals are usually driven in until flush with the top surface of the hub. Refer to Fig. 32-50.

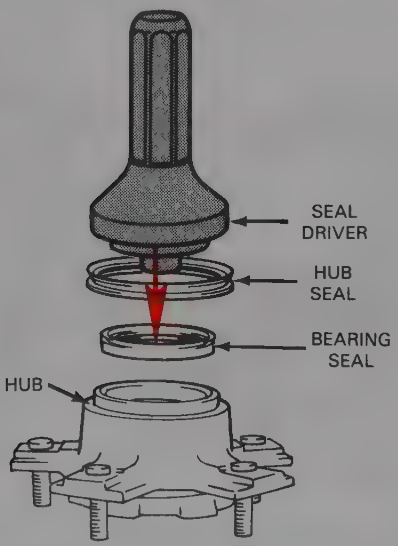


Fig. 32-50. Using a seal driver to install hub and bearing seal. Be sure seals are facing in the proper direction.

If a punch or hammer must be used to seat the seal, strike the seal outer edge only. The inner portion is unsupported and a blow there will destroy the seal. For additional details, see the chapter on gaskets and seals.

Wipe off any grease on the outside of the seal or on the outer hub surface. Install wheel and hub assembly.

INSTALLING WHEEL AND HUB ASSEMBLY

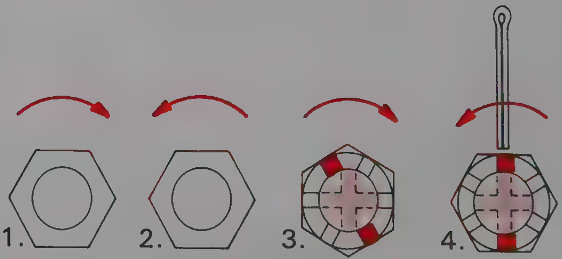
CHECK THE BRAKE SHOES AND BRAKE DRUM FOR GREASE (EVEN FINGERPRINTS). They must be perfectly clean.

Install spacer on spindle where used. Support wheel and slide straight on spindle, Fig. 32-42. Be careful. Do not drag grease seal over spindle threads.

When wheel is in position, insert outer bearing cone, safety thrust washer, and locknut. NEVER FORGET TO INSTALL THE PRONGED SAFETY WASHER. Adjust wheel bearings.

ADJUSTING WHEEL BEARINGS

Proper wheel bearing adjustment is very important. Improper adjustment can cause poor brake performance, wheel shake, poor steering, or rapid bearing wear. See Fig. 32-51 and 32-52.



1—ROTATE WHEEL AND SEAT BEARING BY TIGHTENING NUT TO 10-16 FT.-LB. (13.5-21.6 N·m) TORQUE.
2—LOOSEN NUT UNTIL FREE.
3—RETIGHTEN NUT 20-25 IN.-LB. (2.3-2.8 N·m) TORQUE.
4—LOOSEN NUT UNTIL NEAREST HOLE IN SPINDLE LINES UP WITH A SLOT IN NUT. INSERT COTTER PIN.

Fig. 32-51. One wheel bearing adjustment procedure that utilizes torque wrench. (Pontiac)

Each manufacturer specifies a particular adjustment procedure. Despite variations in technique, most are aimed at securing from .001 to .003 in. (0.0254 to 0.0762 mm) end play for roller bearings and from zero to a mild preload for ball bearings. GENERALLY, MANUFACTURERS CAUTION AGAINST PRELOADING ROLLER BEARINGS.

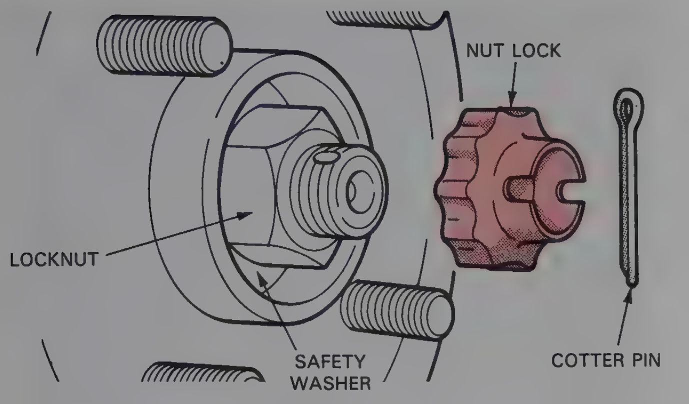

NUT LOCK
LOCKNUT
SAFETY WASHER
COTTER PIN

Fig. 32-52. By using stamped adjustment nut lock, fine wheel bearing adjustment is possible. (Chrysler)

There are several methods that may be used for adjusting wheel bearings. Two of the most accurate and widely recommended will be given. Some wheel bearing assemblies on front-wheel drive vehicles are not serviceable and must be replaced as a unit.

TORQUE WRENCH METHOD OF WHEEL BEARING ADJUSTMENT

In this method the locknut is tightened (spin the wheel in the direction of tightening) to a specified torque. This heavier initial torque is to seat the bearings.

The nut is then unscrewed until finger free. The nut is once again torqued, this time to a lower value. The nut is then carefully backed up until the nearest (or as specified) hole in the spindle aligns with a slot in the nut. See Fig. 32-53.

Another torque wrench method of adjusting wheel bearing preload is illustrated in Fig. 32-54. The nut is tightened to specified torque to seat all of the bearing components, A. The nut is then backed off with torque wrench until loose, B. The nut is then retightened to a recommended torque, C. If cotter pinholes do not line up, slowly back off the nut (not more than around 15 degrees) until holes align.

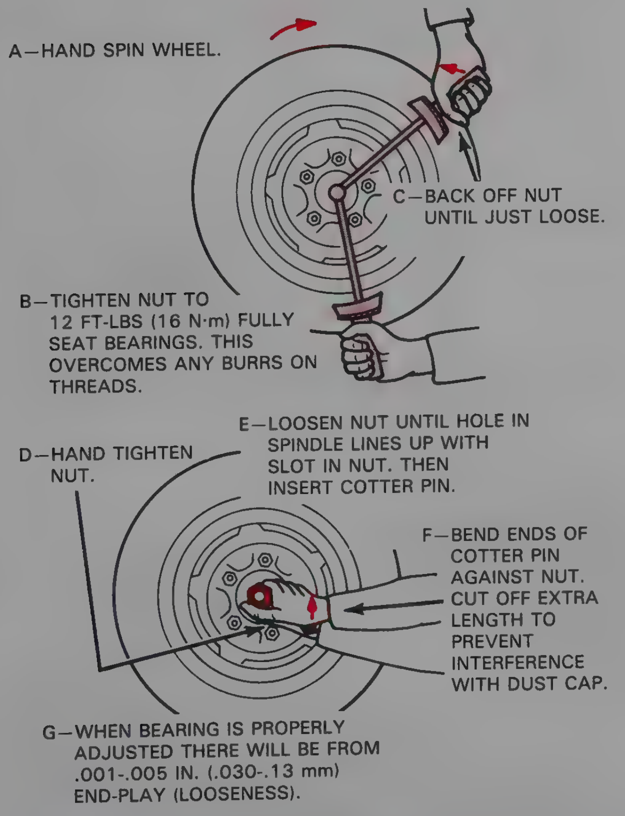

A—HAND SPIN WHEEL.
C—BACK OFF NUT UNTIL JUST LOOSE.
B—TIGHTEN NUT TO 12 FT-LBS (16 N·m) FULLY SEAT BEARINGS. THIS OVERCOMES ANY BURRS ON THREADS.
D—HAND TIGHTEN NUT.
E—LOOSEN NUT UNTIL HOLE IN SPINDLE LINES UP WITH SLOT IN NUT. THEN INSERT COTTER PIN.
F—BEND ENDS OF COTTER PIN AGAINST NUT. CUT OFF EXTRA LENGTH TO PREVENT INTERFERENCE WITH DUST CAP.
G—WHEN BEARING IS PROPERLY ADJUSTED THERE WILL BE FROM .001-.005 IN. (.030-.13 mm) END-PLAY (LOOSENESS).

Fig. 32-53. One torque wrench method of wheel bearing adjustment with tire and wheel on vehicle. (Cadillac)

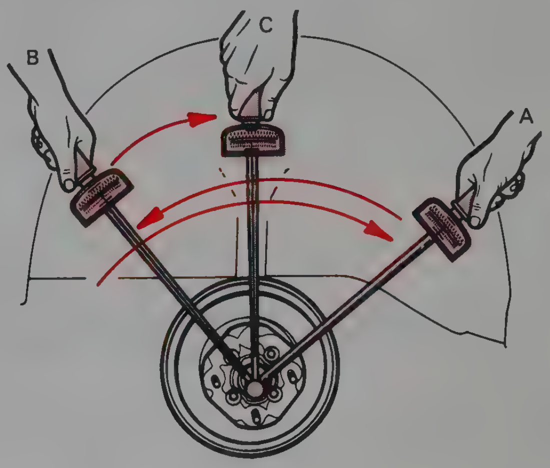


Fig. 32-54. Adjusting wheel bearing preload with a torque wrench. (Dodge)

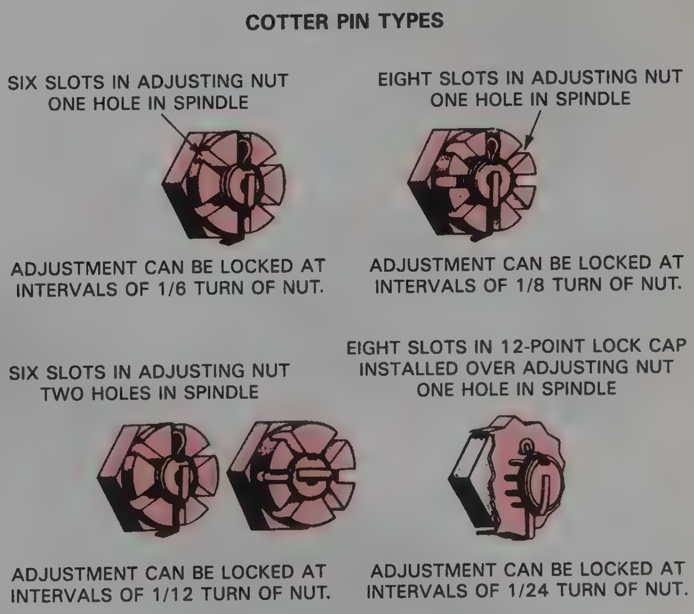

COTTER PIN TYPES
SIX SLOTS IN ADJUSTING NUT ONE HOLE IN SPINDLE
EIGHT SLOTS IN ADJUSTING NUT ONE HOLE IN SPINDLE
ADJUSTMENT CAN BE LOCKED AT INTERVALS OF 1/6 TURN OF NUT.
ADJUSTMENT CAN BE LOCKED AT INTERVALS OF 1/8 TURN OF NUT.
SIX SLOTS IN ADJUSTING NUT TWO HOLES IN SPINDLE
EIGHT SLOTS IN 12-POINT LOCK CAP INSTALLED OVER ADJUSTING NUT ONE HOLE IN SPINDLE
ADJUSTMENT CAN BE LOCKED AT INTERVALS OF 1/12 TURN OF NUT.
ADJUSTMENT CAN BE LOCKED AT INTERVALS OF 1/24 TURN OF NUT.

Fig. 32-55. Various front wheel bearing locknuts.

Some cars use a stamped nut lock that fits over the regular nut. This provides a finer adjustment in that more combinations of nut position and alignment with the cotter pin holes are available, Fig. 32-52.

This special lock cap is compared with other nut types in Fig. 32-55. Note that the nut may be adjusted as little as 1/24 turn.

Another technique employing a torque wrench, when the special stamped locking nut is used, is illustrated in Fig. 32-56.

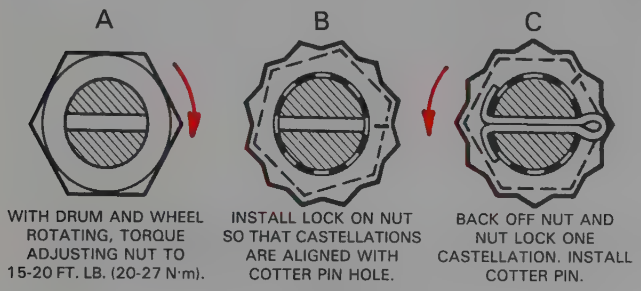

A
B
C
WITH DRUM AND WHEEL ROTATING, TORQUE ADJUSTING NUT TO 15-20 FT. LB. (20-27 N·m).
INSTALL LOCK ON NUT SO THAT CASTELLATIONS ARE ALIGNED WITH COTTER PIN HOLE.
BACK OFF NUT AND NUT LOCK ONE CASTELLATION. INSTALL COTTER PIN.

Fig. 32-56. Adjusting wheel bearing using stamped adjustment nut. (Ford)

The adjusting nut is tightened to around 20 ft.-lb. (27 N·m) while spinning the wheel. See A, Fig. 32-56. The stamped locknut is then tried over the adjusting nut until one of the slots or castellations is aligned with the cotter pin hole in the spindle, B. The adjusting nut and locknut are then carefully backed off (together) one castellation. The cotter pin is then inserted, C.

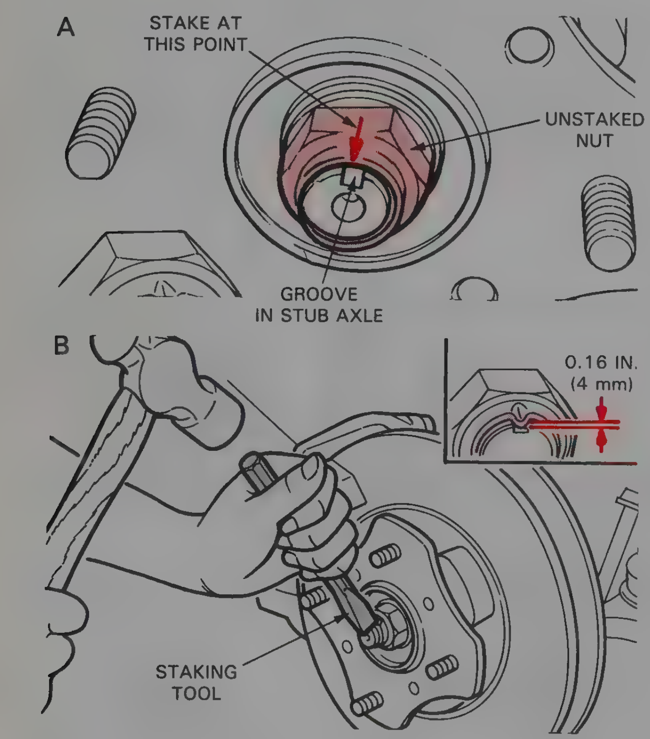

A
STAKE AT THIS POINT
UNSTAKED NUT
GROOVE IN STUB AXLE
B
0.16 IN. (4 mm)
STAKING TOOL

Fig. 32-57. Staking wheel nut to prevent rotation. A—An unstaked nut. Note groove in stub axle. B—Staking tool being used to force nut lip into axle groove. Note proper staking depth. (Mazda)

Some vehicles equipped with front-wheel drive employ a special "STAKED NUT" in place of a cotter pin. Look at Fig. 32-57.

The nut has an integral, thin lip that is forced into a groove cut in the axle stub shaft with a special tool. Do not use a sharp edged tool for staking. When the nut is removed, it MUST be discarded. Near perfect bearing adjustment can be obtained using this method.

DIAL INDICATOR METHOD OF ADJUSTING FRONT WHEEL BEARINGS

Tighten the adjusting nut with medium size adjustable wrench.

Tighten firmly while spinning wheel. Back adjusting nut up slowly until just finger free.

Attach a dial indicator so that the indicator stem just contacts the machined end (outer side) of the hub, Fig. 32-58. Grasp the sides of the rotor or the tire and pull straight in and out. Read gauge for amount of end play. Adjust nut until end play is within maker's specifications.

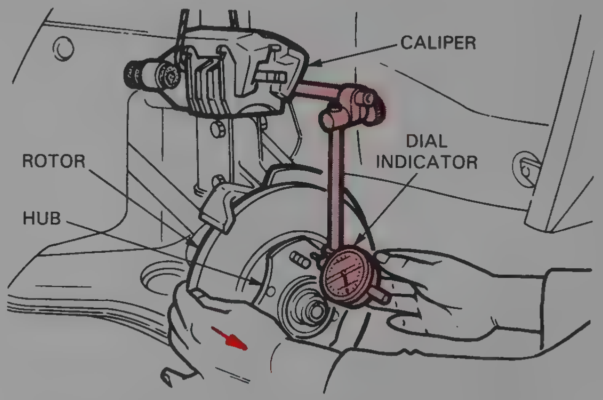

CALIPER
ROTOR
DIAL INDICATOR
HUB

Fig. 32-58. Dial indicator being used to check bearing play. Note that caliper has been removed. This makes accurate measuring easier. (Mazda)

The dial indicator may be mounted to the spindle nut with the indicator touching the hub end. It may also be mounted to a wheel stud with the indicator stem contacting the end of the spindle, Fig. 32-59.

Regardless of technique used, when the adjustment is correct, the wheel will spin SMOOTHLY, FREELY, and with no appreciable side shake. DO NOT CONFUSE BALL JOINT OR SUSPENSION ARM BUSHING WEAR WITH WHEEL BEARING LOOSENESS.

If in doubt, mount a dial indicator as described and check actual end play.

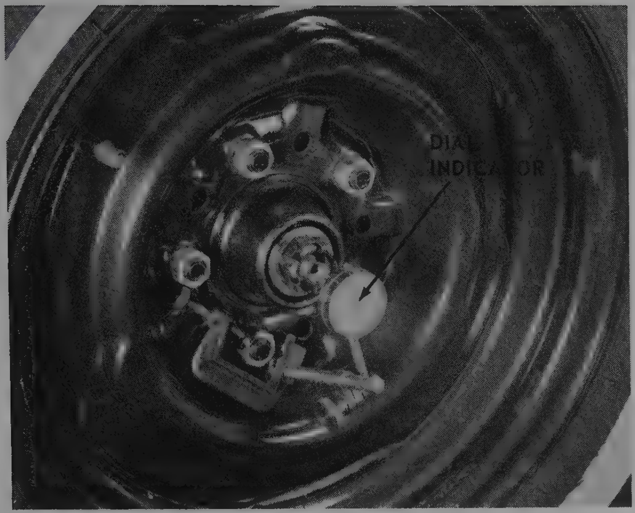


Fig. 32-59. Dial indicator mounted to wheel lug nut. Stem rests against end of spindle.

REMEMBER: For most roller wheel bearings, adjust so that end play ranges from .001 to .005 in. (0.025 to 0.127 mm). For ball bearings, adjust from zero to a mild preload. Check a service manual for details. Bearing service is illustrated in Fig. 32-60.

NOTE FOR CARS USING FRONT DISC BRAKES

To avoid interference by brake friction pads, loosen wheel bearing adjusting nut about three turns and wobble wheel back and forth to force friction pad apply pistons back into their bores. Bearing may now be adjusted as described.

DISC BRAKES REQUIRE VERY CAREFUL ADJUSTMENT OF THE WHEEL BEARINGS. FOR ROLLER BEARINGS, STRIVE FOR ZERO TO .001 IN. (ZERO TO 0.025 MM) END PLAY. EXCESSIVE END PLAY ALLOWS THE DISC TO WOBBLE.

INSTALL COTTER PIN PROPERLY

Tap the head of the cotter pin firmly into the castellation. Cut pin to a length that will permit bending the ends, as shown in Fig. 32-55. If a static collector is used in the dust cap, make certain the end of the pin bent over the spindle is short enough so that it will not hit the collector prong.

The cotter pin may be installed as pictured in Fig. 32-56.

Regardless of the technique used for bending the pin ends, always use a new cotter pin. Use as thick a pin as can be passed through the hole. Make certain the pin is tight after the ends are bent. A loose pin can break from vibration.

Install dust cover. Use new O-ring or sealer where required.

LAST CHECK FOR SAFETY WASHER, COTTER PIN, STAKED NUT

ALWAYS MAKE A FINAL CHECK BEFORE INSTALLING THE DUST CAP TO MAKE CERTAIN

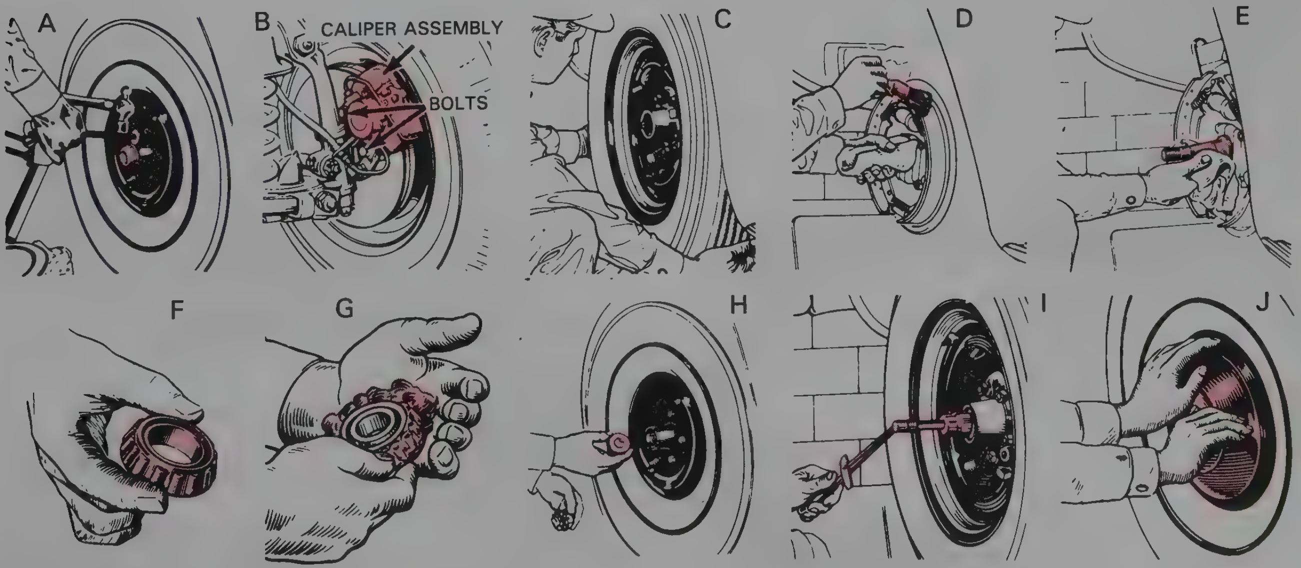


Fig. 32-60. Some of the major steps in wheel bearing service. A—Remove dust cap. B—Remove brake caliper where used. C—Remove cotter pin, adjusting nut, and pull wheel. D—Cover spindle and clean brake assembly. E—Clean, inspect, and lube spindle. F—Clean and inspect wheel bearings. G—Pack bearings. H—Lube hub. Install bearings and grease seal. Install wheel, outer bearing, safety washer, and adjusting nut. I—Adjust bearings. Install cotter pins and dust cover. J—Install wheel cover or hub cap. (Shell)

THAT THE SAFETY WASHER, COTTER PIN, AND STAKED NUT ARE PROPERLY INSTALLED.

TIRE LOAD INFORMATION LABEL

A tire load information label can be found on most vehicles. It is generally located on the driver's door, on the door pillar, or inside the glove box. The load information label contains specific information on maximum vehicle load, tire size (including spare tire), and inflation pressures.

TIRE SIZE

Tire size is now generally determined by alphabetical-numerical or by metric sizing, such as P205/75R15. The letter P indicates the tire is designed for a passenger vehicle. The number "205" represents the tire's section width in millimetres. The number "75" is the aspect ratio (relationship of a tire's cross-sectional height to its width). This means that this tire's height (B, in Fig. 32-61) is 75 percent of its width. "R" indicates radial ply construction. The final number "15" is the rim diameter in inches. Study the markings in Fig. 32-61 carefully.

CAUTION! DO NOT MIX RADIAL PLY TIRES WITH BIAS OR BIAS-BELTED TIRES ON THE SAME VEHICLE. POOR VEHICLE HANDLING WILL RESULT.

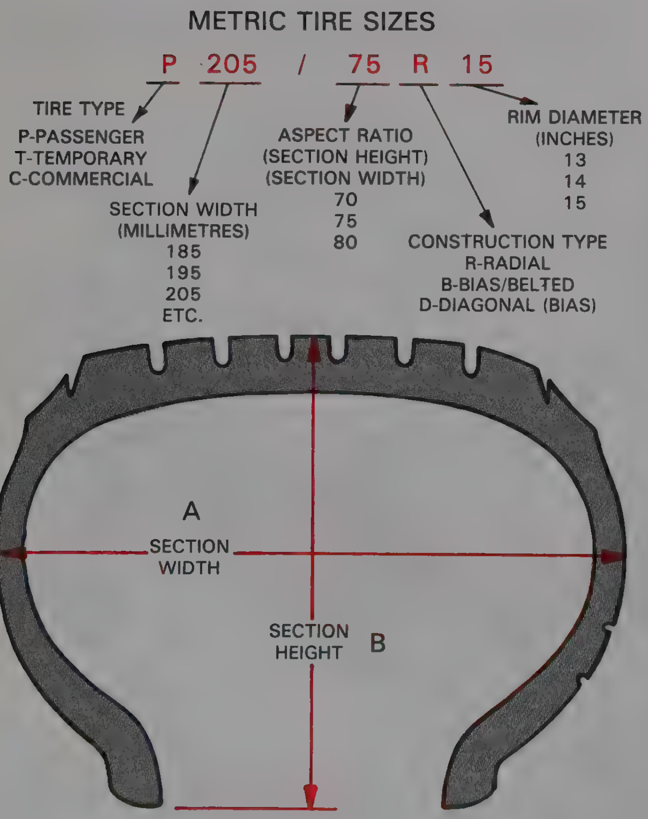

METRIC TIRE SIZES
P 205 / 75 R 15
TIRE TYPE
P-PASSENGER
T-TEMPORARY
C-COMMERCIAL
SECTION WIDTH
(MILLIMETRES)
185
195
205
ETC.
ASPECT RATIO
(SECTION HEIGHT)
(SECTION WIDTH)
70
75
80
RIM DIAMETER
(INCHES)
13
14
15
CONSTRUCTION TYPE
R-RADIAL
B-BIAS/BELTED
D-DIAGONAL (BIAS)
A
SECTION
WIDTH
SECTION
HEIGHT
B

Fig. 32-61. Metric tire size chart with meanings. (Chevrolet)

WHEEL RIM SIZE

Rim size is determined by three measurements: rim width, rim diameter, and flange height. Rim width and diameter are measured in inches. Flange height is identified by letters (J, K, etc.). The flange letter indicates a definite flange height. For example, a K rim flange is 0.77 in. (19.5 mm) high. See Fig. 32-62.

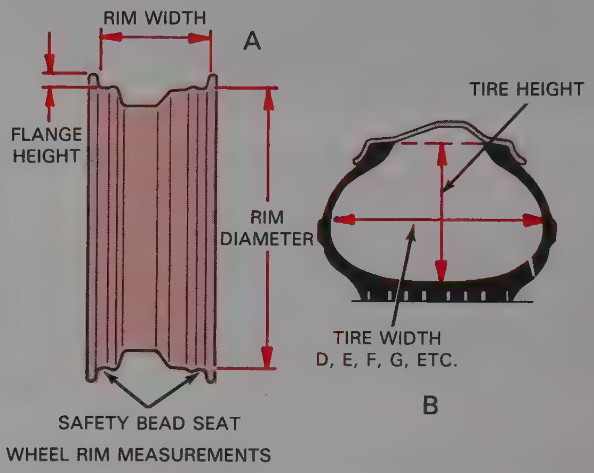

RIM WIDTH
A
FLANGE
HEIGHT
RIM
DIAMETER
TIRE HEIGHT
TIRE WIDTH
D, E, F, G, ETC.
B
SAFETY BEAD SEAT
WHEEL RIM MEASUREMENTS

Fig. 32-62. A—Rim size is identified by rim width, rim diameter, and flange height. Note safety bead seats. These are used to keep the tire on the rim in event of tire failure. B—Tire height, as related to tire width, determines the aspect ratio. If tire height was 78 percent of tire width, the aspect ratio would be 78. (Dodge and Firestone)

TIRE CORD MATERIALS

Rayon, nylon, polyester, aramid, kevlar, and fiberglas are used as cord materials. Steel wire is sometimes used in the belt section of radial type tires. Other materials are also being tested and evaluated.

CORD CONSTRUCTION (ANGLE)

One tire construction technique involves the use of two or four plies (layers of cord material) laid at an angle to the tire centerline. Look at A, Fig. 32-63. This is termed BIAS construction.

Another method of arranging the plies is illustrated in B. This is called a "bias-belted" cord arrangement. Note the difference in cord angles between A and B.

The third type of construction is radial. Note that the body cords cross the tire centerline almost at right angles to the belts, C, Fig. 32-63.

Fig. 32-64 shows a cutaway view of a radial tire.

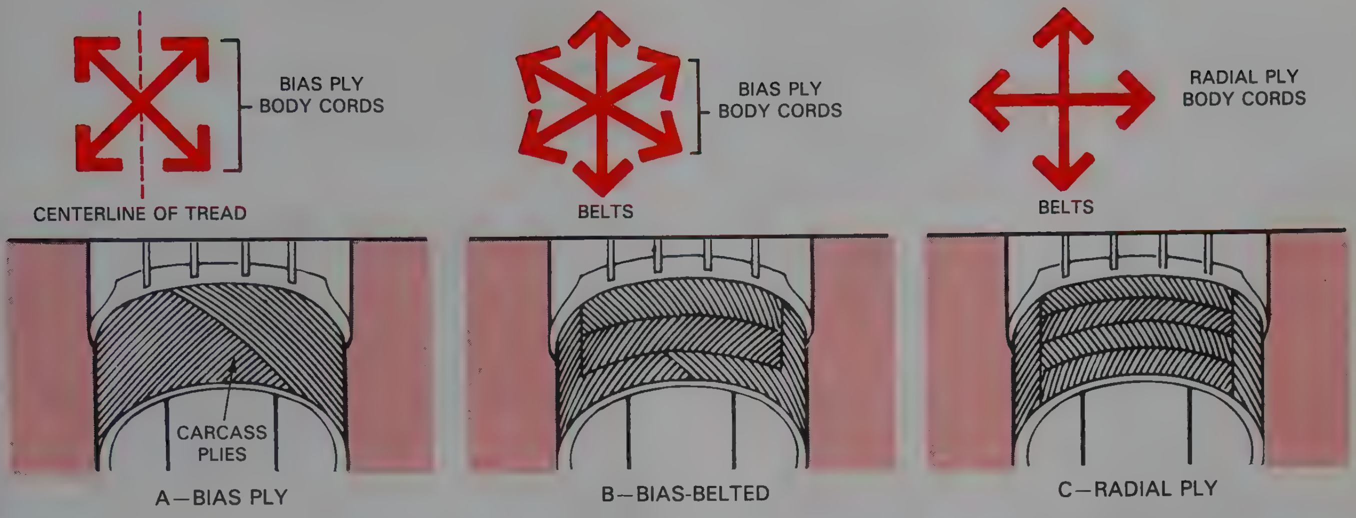

BIAS PLY
BODY CORDS
CENTERLINE OF TREAD
CARCASS
PLIES
A—BIAS PLY
BIAS PLY
BODY CORDS
BELTS
B—BIAS-BELTED
RADIAL PLY
BODY CORDS
BELTS
C—RADIAL PLY

Fig. 32-63. Three methods of arranging tire cord. Note arrows above each ply method. These indicate direction of ply cords. (Goodyear)

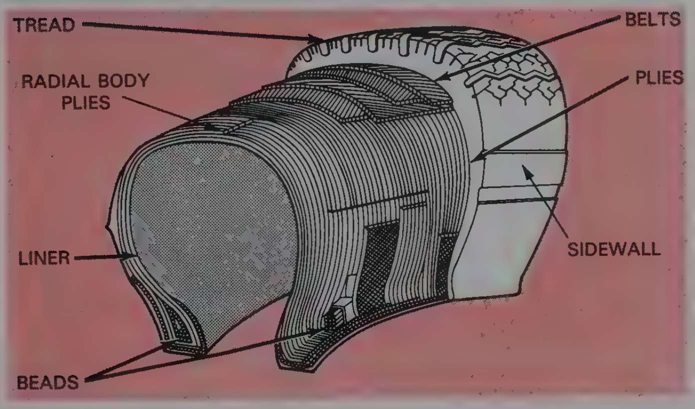

TREAD
BELTS
RADIAL BODY
PLIES
PLIES
LINER
SIDEWALL
BEADS

Fig. 32-64. Cutaway view of one particular radial ply tire. (Chrysler)

TIRE PRESSURE IS IMPORTANT

Tires must be inflated to recommended pressures. An underinflated tire will cause the sidewalls to flex excessively and will quickly generate damaging heat. In addition the tread will buckle up (away from road) in the center and thus cause rapid wear on the tire edges. See A, Fig. 32-65.

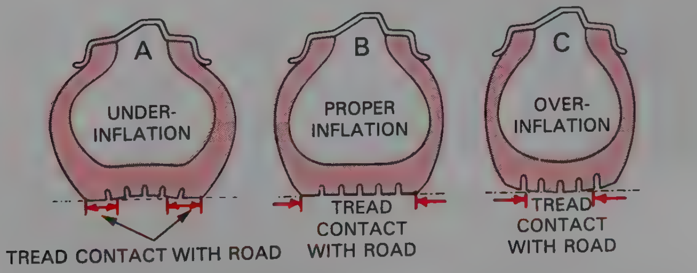

A
UNDER-
INFLATION
TREAD CONTACT WITH ROAD
B
PROPER
INFLATION
TREAD
CONTACT
WITH ROAD
C
OVER-
INFLATION
TREAD
CONTACT
WITH ROAD

Fig. 32-65. Effect of inflation pressure on tire tread-to-road contact. (Rubber Mfg. Assoc.)

Overinflation will make the tire ride hard and will also make it more susceptible to casing (ply) breakage. Note how the overinflated tire, C, Fig. 32-65, bulges in the center, thus pulling the edges of the tire away from the road. This produces rapid wear in the center.

To provide proper steering, ride, wear, and dependability, keep the tire pressures within the recommended range of the manufacturer. Note how the full tread width of the correctly inflated tire, B, Fig. 32-65, contacts the surface of the road.

Inflate tires to recommended pressure when COLD (prevailing atmospheric temperature). A tire may be considered cold after standing out of direct sunlight for 3 or 4 hours.

Remember! When tires are driven, their temperature rises. The rise will depend upon speed, load, road smoothness, and prevailing temperature. A cold tire at 24 psi (165 kPa) will build up pressure to about 29 psi (200 kPa) after 4 miles (6.4 km) at speeds over 40 mph (64.4 km/h).

When checking HOT (in service) tires, pressure will exceed COLD specifications. Never let air out of hot tires to get specified cold pressure. For heavy loads or sustained high speed driving, many makers recommend increasing cold pressure 4 psi (25 kPa).

TIRE ROTATION

Tire life can be extended by periodic tire rotation. The front tires are placed at the rear before any front wheel misalignment can cause serious tire unbalance or tire wear.

Rotate tires about every 5,000 miles (8 000 km). Fig. 32-66 shows popular methods of rotation, using both conventional and radial tires.

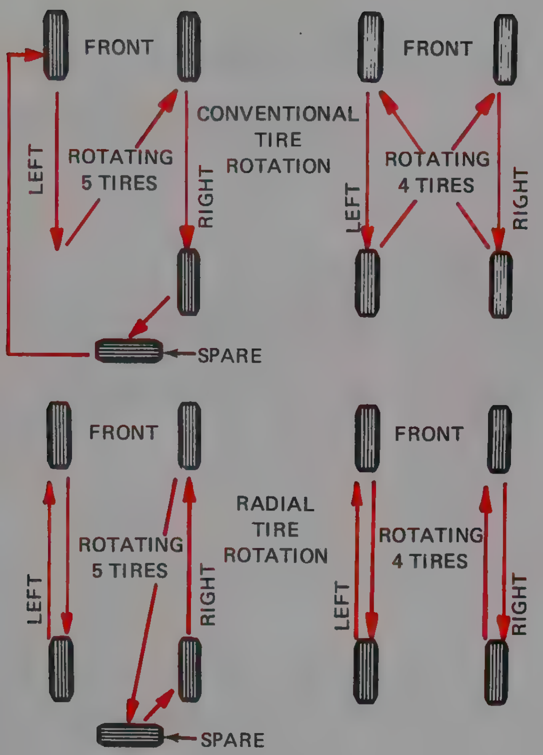

FRONT
LEFT
ROTATING
5 TIRES
RIGHT
SPARE
CONVENTIONAL
TIRE
ROTATION
FRONT
LEFT
ROTATING
4 TIRES
RIGHT
FRONT
LEFT
ROTATING
5 TIRES
RIGHT
SPARE
RADIAL
TIRE
ROTATION
FRONT
LEFT
ROTATING
4 TIRES
RIGHT

Fig. 32-66. Tire rotation chart for both conventional and radial tires. (American Motors)

CAUTION! Some manufacturer's do not recommend radial tire rotation. Tires must be ALL replaced or replaced in PAIRS when they reach their maximum wear limit. DO NOT rotate in the compact (space saver type) spare tire. They are for emergency driving only.

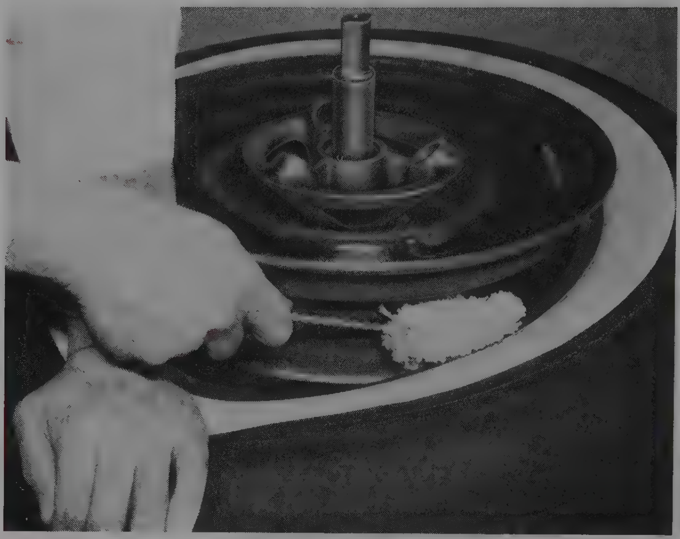


Fig. 32-67. Always apply approved rubber lubricant before demounting a tire. (Big Four Industries)

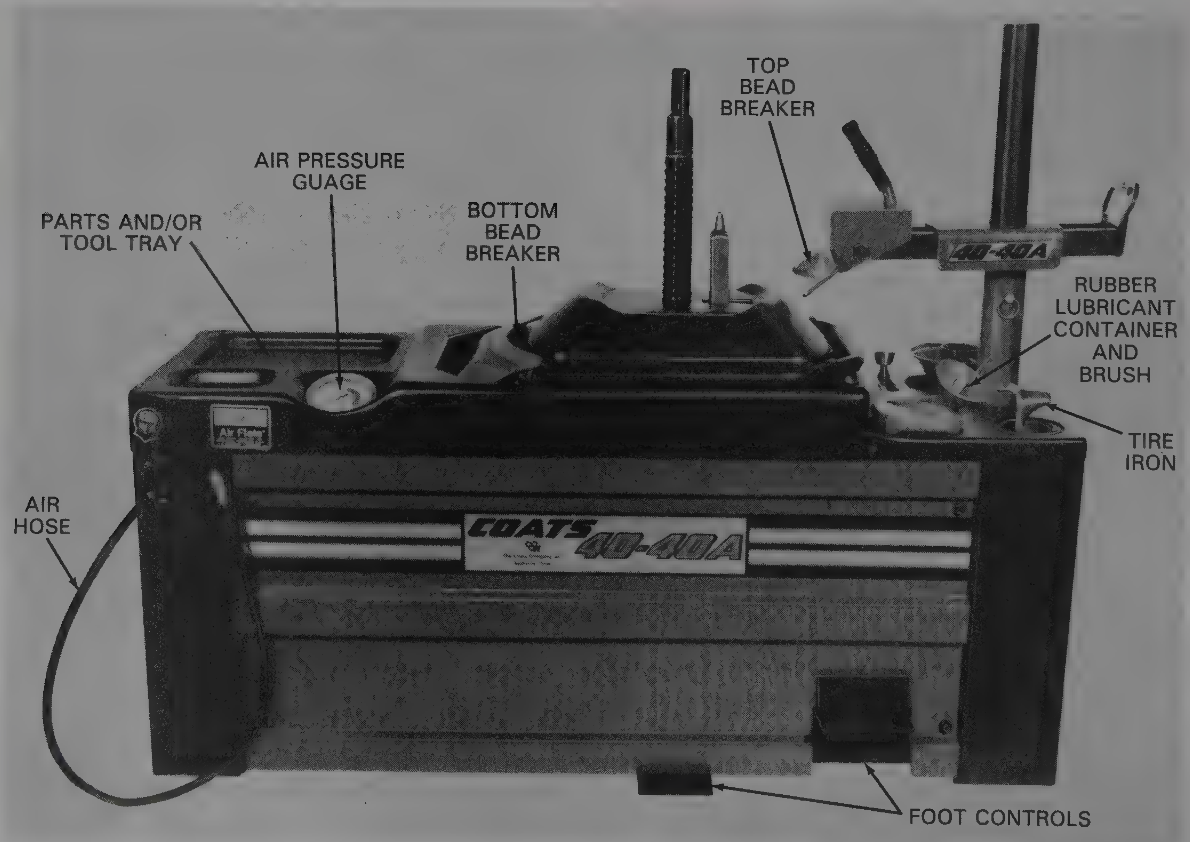

TOP
BEAD
BREAKER
AIR PRESSURE
GUAGE
PARTS AND/OR
TOOL TRAY
BOTTOM
BEAD
BREAKER
RUBBER
LUBRICANT
CONTAINER
AND
BRUSH
TIRE
IRON
AIR
HOSE
COATS 40-40A
FOOT CONTROLS

Fig. 32-68. Air powered tire changer units, such as this one, speed up handling and offer greater protection from tire damage. Note air hose and gauge. Tire can be properly inflated and beads seated without moving to anotner location. (Coats)

TIRE DEMOUNTING AND MOUNTING

Use proper equipment to demount and mount tires. Use care to avoid damaging bead sealing surfaces. Always use an approved rubber lubricant before demounting and mounting. Otherwise, you may tear the sealing surface and/or cause excessive strain on the bead wire, especially on safety rims. Refer to Figs. 32-67 and 32-68.

Before mounting a tire on a wheel, clean off the rim sealing area with coarse steel wool. Peen over loose or leaking rivets. File off nicks and burrs. Straighten any dented area on the sealing flanges (edges), Fig. 32-69.

Be sure, when mounting tires such as radials, that the wheel is approved for their use.

Wheels with low tire pressure warning systems require special care when mounting and demounting tires. Never use tire inflators that contain puncture sealant in these systems. Follow all manufacturer's recommendations.

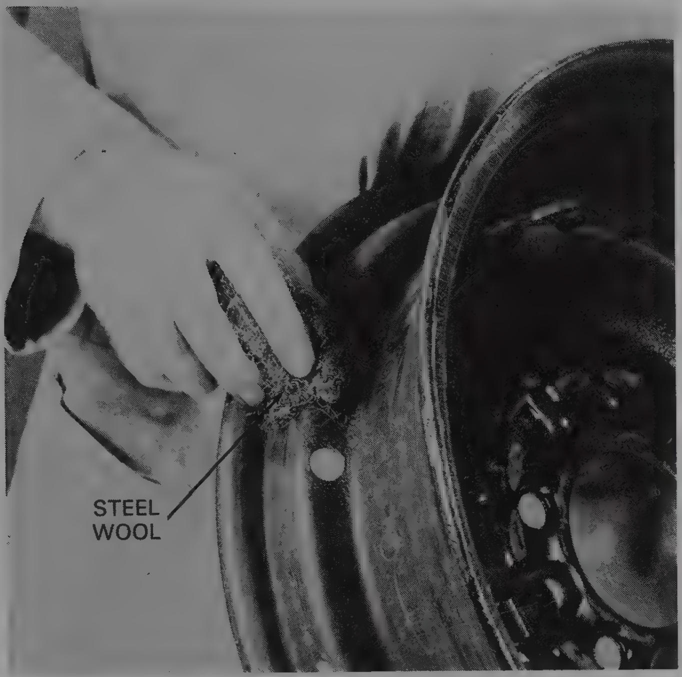
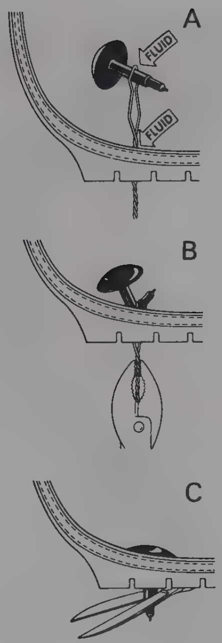


Fig. 32-69. Clean the rim and check for cracks, dents, and wheel weights before mounting tire. (Rubber Mfg. Assoc.)

REPAIRING A PUNCTURED TIRE

Better puncture repairs can be made by demounting the tire. Remove the puncturing object, noting the angle of penetration. Clean the puncture area with a special tool. Then apply a solvent lubricant to the hole.

Using a special tool, pull a rubber plug or rivet through the tire. Cut off as directed, Fig. 32-70. If you put in a straight rubber plug, apply a patch over the plug end inside the tire.



INSERT WIRE LEADER INTO HOLE, THEN APPLY A LIBERAL DAB OF SOLVENT LUBRICANT ON ENTIRE STEM OF RIVET AND AT HOLE.

GRIP END OF WIRE LEADER WITH PLIERS AND WITH A QUICK FIRM YANK, PULL RIVET STEM THROUGH CASING.

CUT OFF STEM TO WITHIN 1/8 IN. OF TREAD. THE PROTRUDING UNCOMPRESSED SHANK ACTS AS A "HEAD" AND FORMS THE THIRD SEAL.

Fig. 32-70. Repairing a puncture in a tubeless tire. (Schrader)

Punctures, not larger than 1/2 in. (12.7 mm), can be repaired by inserting a rubber plug through the tire without demounting, Fig. 32-71. Reduce tire pressure to 10 psi (69 kPa) or less. Follow manufacturer's directions.

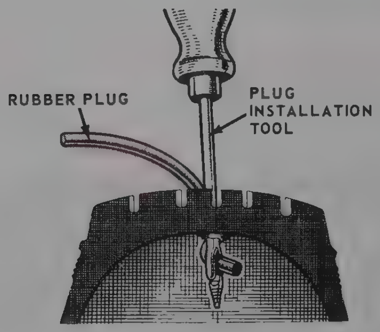


Fig. 32-71. Repairing puncture in tubeless tire by passing rubber plug through tire from outside. (British-Leyland)

Certain tires (generally radials) have a repairable and nonrepairable area, Fig. 32-72.

NEVER repair a tire with:

1. Ply separation.
2. Damaged bead wires.
3. Tread separation.
4. Loose cords.
5. Cuts or cracks that extend into the tire cord (fabric) material.
6. Tread wear indicators showing.

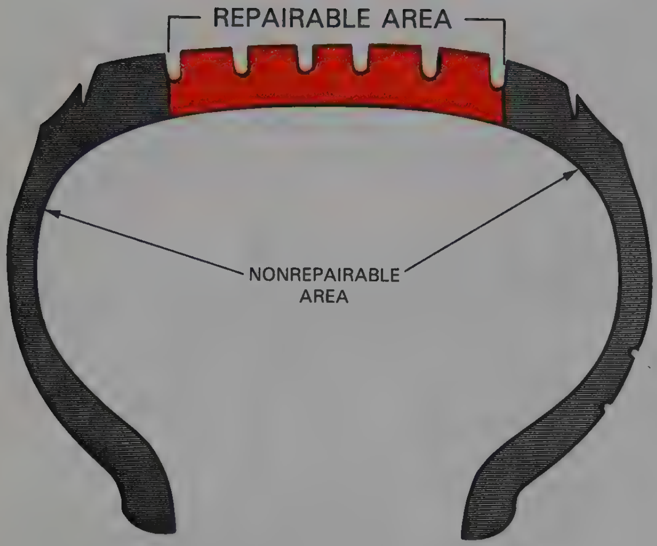


Fig. 32-72. Cross section of a radial tire showing repairable and nonrepairable areas. Always check maker's recommendations. (Chevrolet)

SEATING TIRE BEADS FOLLOWING MOUNTING

On some tires, the use of a bead expander or seal ring will help trap sufficient air to inflate a tubeless tire.

Remove expander before pressure exceeds 10 psi (69 kPa). Seal ring, as illustrated in Fig. 32-73, moves up wheel as tire inflates until it slips off as upper bead is seated.

STAY AWAY FROM TIRE WHILE INFLATING

MUCH HAS BEEN SAID ABOUT THE DANGER OF INFLATING TRUCK TIRES WITH DEMOUNTABLE RIM FLANGES. WHAT MANY PERSONS FAIL TO REALIZE IS THAT THE ORDINARY CAR TIRE AND RIM CAN ALSO EXPLODE WITH EXTREME VIOLENCE.

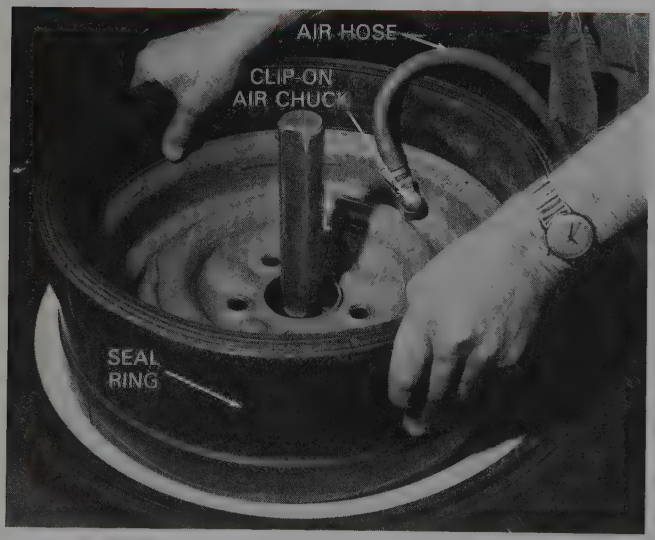


Fig. 32-73. Special rubber coated seal ring being used to help seat lower tire bead and hold air until upper bead seats. Keep fingers from under ring while using! (Goodyear)

NEVER EXCEED MAXIMUM BEAD SEATING PRESSURE, GENERALLY 40 PSI (276 kPa).

DO NOT INFLATE TIRES WITH AIR CONTAMINATED WITH OIL, GASOLINE, OR CLEANING SOLVENTS BECAUSE TIRE DAMAGE OR EXPLOSION CAN OCCUR.

When inflating the tire, use a liberal amount of rubber lubricant (not silicone). Use a clip-on air chuck to attach the air hose to the valve stem. Back away from the tire while inflating. Never exceed a pressure of 40 psi (276 kPa) in an endeavor to force the beads out against the rim flanges. If difficulty is experienced, deflate the tire. Check for the source of trouble.

REMEMBER! When a tire bead is being forced into place, it can cock to one side and bind. If air pressure is allowed to exceed 40 psi (276 kPa), the wire bead can snap. This can allow the bead edge to explode outward against the rim flange with such force that the flange is sheared off.

SHOW RESPECT! STAY AWAY FROM THE TIRE WHILE SEATING THE BEADS. MANY SERVICE PEOPLE DID NOT AND PAID FOR THIS CARELESSNESS WITH THEIR LIVES.

Reduce air pressure to normal running level following bead seating. Look at Fig. 32-74.

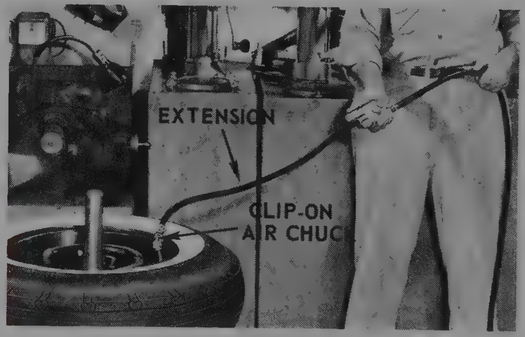


Fig. 32-74. Stay away from tire while seating beads.

TIRE WEAR PATTERNS

An inspection of the tires will often reveal the cause of rapid or uneven tread wear. Although many causes or combination of causes can be responsible, UNDERINFLATION, OVERINFLATION, TOE, CAMBER, AND CORNERING WEAR account for most problems.

Underinflation causes rapid edge or shoulder wear, A, Fig. 32-75. Overinflation wears out the center of the tread, B.

Excessive toe-in or toe-out will cause extremely rapid

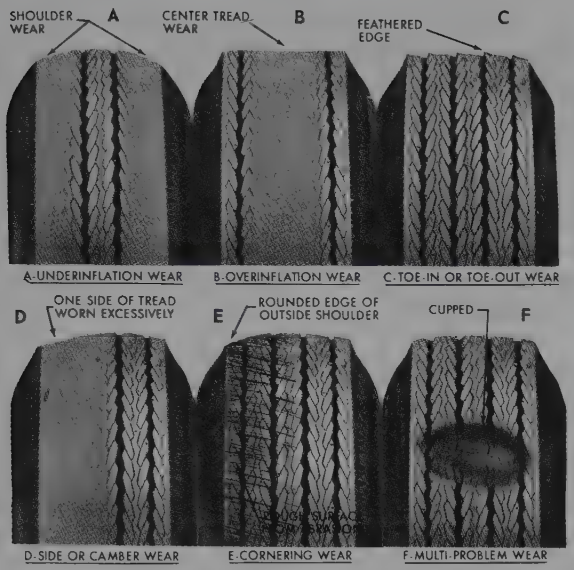

SHOULDER WEAR
A
CENTER TREAD WEAR
B
FEATHERED EDGE
C
A-UNDERINFLATION WEAR
B-OVERINFLATION WEAR
C-TOE-IN OR TOE-OUT WEAR
D
ONE SIDE OF TREAD WORN EXCESSIVELY
E
ROUNDED EDGE OF OUTSIDE SHOULDER
CUPPED
F
D-SIDE OR CAMBER WEAR
E-CORNERING WEAR
F-MULTI-PROBLEM WEAR

Fig. 32-75. Tread wear patterns indicative of pressure, alignment, or driving problems. (Buick)

wear and will be evidenced by feathered edges as in C. Improper camber angle wears one side of the tread, D. Excessive speed around corners will generally cause a rounding of the outside shoulder. There are certain similarities to toe wear in some cases, E. A combination of causes can produce numerous wear patterns. One common symptom of combination wear is a series of cupped out spots around the tire, F.

When tires show wear patterns as illustrated in Fig. 32-75, corrective measures are needed.

SPECIAL SERVICE TIRES

Many safety and high-speed tires are available. High-speed tires generally use steel wires in the outer ply-tread area. Steel resists expansion from centrifugal force, which helps to control distortion. They also resist punctures better than fabric belts.

A good number of vehicles are now equipped with a COMPACT spare tire. It is designed to take up less cargo space and is lighter than a normal tire.

The compact spare tire is for "TEMPORARY USE ONLY." Use it to replace a flat until repaired or replaced. DO NOT "rotate in" with the other tires. When replacing this tire, mount ONLY on a special wheel designed for its use. DO NOT use hub caps or wheel covers on the rim. Possible tire damage could result. Keep inflated to recommended pressure. A compact spare tire is pictured in Fig. 32-76.

TIRE GRADING

Many tires now being produced are graded by the UNIFORM TIRE QUALITY GRADING SYSTEM (UTQGS).

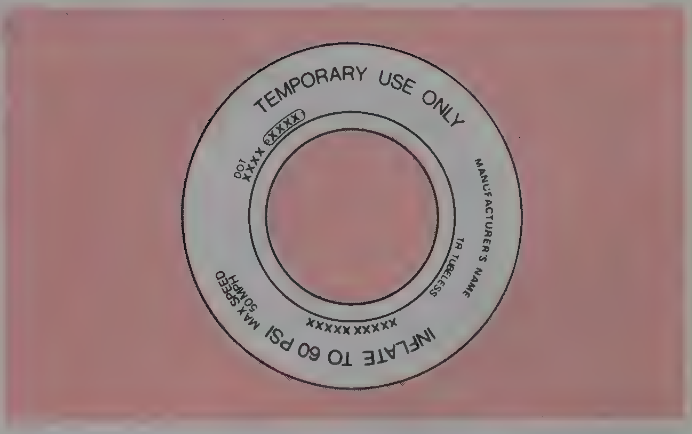

TEMPORARY USE ONLY
DOT XXXX (XXXX)
MANUFACTURER'S NAME
TR TUBELESS
XXXXX XXXXX
INFLATE TO 60 PSI
MAX SPEED 50MPH

Fig. 32-76. Compact spare tire. Note important information listed on tire sidewall. (Mazda)

Grading consists of a series of numbers and letters which rate temperature resistance, traction, and tread wear.

TEMPERATURE RESISTANCE rating has three letter-grade levels: A, B, and C. "A" offers the greatest resistance to heat generation. "C" provides the least.

TRACTION, like temperature resistance, is also graded on three levels: A, B, and C. "A" offers best traction (wet roads), while "C" offers the smallest amount.

TREAD WEAR is graded by using a set of numbers: 90, 100, 120, 130, etc. A tire that has a tread wear grade of 150 should supply approximately 50 percent more mileage than a tire with a tread wear rating of 100.

WHEEL AND TIRE BALANCE

Irregularities in construction, shifting of the weight mass from tread wear, and other problems can cause the tire and wheel assembly to be unbalanced.

With today's highway speeds, even a slight unbalance can cause wheel tramp (tire and wheel hopping up and down) or wheel shimmy (shaking from side to side). Wheel assemblies must be in both STATIC AND DYNAMIC balance.

STATIC BALANCE

To be in static balance, the weight mass must be evenly distributed around the axis of rotation. See Fig. 32-77, A. A wheel in static balance will remain in any position, whereas static unbalance will cause the heavy side to rotate to the bottom.

The wheel is brought into static balance by clipping weights to the rim opposite the heavy side. If more than 2 ounces (56 g) of weight is required, the weight should be split by adding one-half of the required amount to the inside of the rim and the remainder to the outside. By placing half of the weight on each side, dynamic balance will not be disturbed. Look at Fig. 32-77, B.

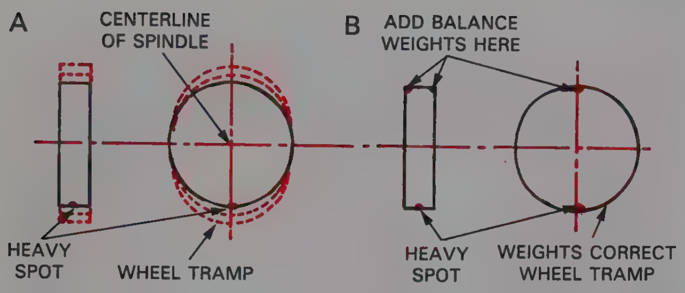

A
CENTERLINE OF SPINDLE
HEAVY SPOT
WHEEL TRAMP
B
ADD BALANCE WEIGHTS HERE
HEAVY SPOT
WEIGHTS CORRECT WHEEL TRAMP

Fig. 32-77. Wheel brought into static balance by adding balance weights to light side. Note how weights were split with one-half placed on each side of rim. (Pontiac)

DYNAMIC BALANCE

To be in dynamic balance, the centerline of the weight mass must be in the same plane as the centerline of the wheel.

Fig. 32-78 shows a wheel and tire assembly that is dynamically unbalanced. Note how the weight mass centerline fails to coincide with the plane of the wheel centerline.

When the wheel rotates, centrifugal force attempts to force the weight mass to align with the wheel centerline. Since the direction of this force is one way on one side of the assembly, and the other on the opposite side, A, it causes the wheel to shimmy, B.

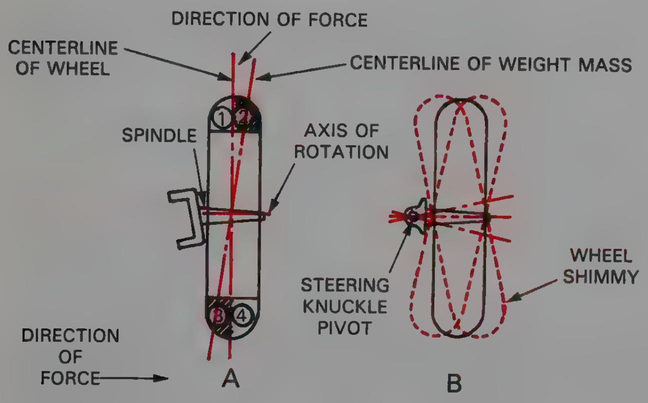

DIRECTION OF FORCE
CENTERLINE OF WHEEL
CENTERLINE OF WEIGHT MASS
SPINDLE
AXIS OF ROTATION
1
2
3
4
STEERING KNUCKLE PIVOT
WHEEL SHIMMY
DIRECTION OF FORCE
A
B

Fig. 32-78. Dynamically unbalanced wheel and tire assembly. (Plymouth)

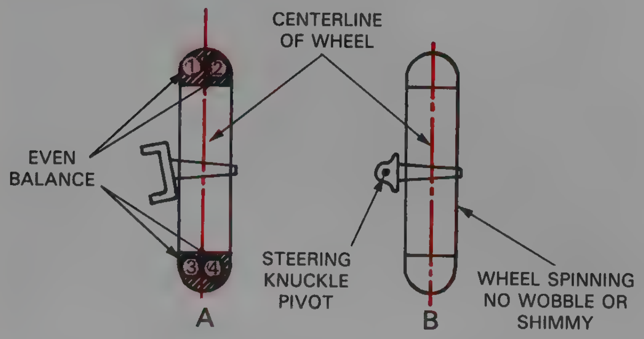

CENTERLINE OF WHEEL
1
2
EVEN BALANCE
3
4
STEERING KNUCKLE PIVOT
WHEEL SPINNING NO WOBBLE OR SHIMMY
A
B

Fig. 32-79. Dynamically balanced tire and wheel assembly.

Dynamic unbalance is corrected by adding wheel balance weights in amounts sufficient to bring the weight mass and wheel centerlines into the same plane.

To be in dynamic balance, the assembly must also be in static balance.

Fig. 32-79 pictures a dynamically balanced wheel and tire assembly. Note how the wheel and weight mass centerlines coincide, A. When the wheel rotates, there is no shimmy, B.

BEFORE BALANCING, CHECK WHEEL AND TIRE RUNOUT

A wheel and tire assembly with excessive lateral or radial runout cannot be balanced properly. Always check runout BEFORE balancing. Check runout at the points indicated in Fig. 32-80.

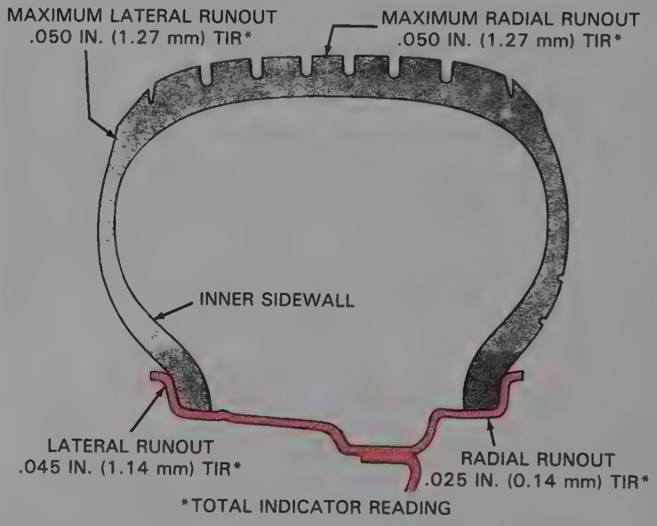

MAXIMUM LATERAL RUNOUT .050 IN. (1.27 mm) TIR*
MAXIMUM RADIAL RUNOUT .050 IN. (1.27 mm) TIR*
INNER SIDEWALL
LATERAL RUNOUT .045 IN. (1.14 mm) TIR*
RADIAL RUNOUT .025 IN. (0.14 mm) TIR*
*TOTAL INDICATOR READING

Fig. 32-80. Check wheel and tire at these points with a dial indicator. (Cadillac)

Generally, tire radial and lateral runout should be kept within the figures shown in Fig. 32-80. When possible, use a dial indicator setup as shown in Fig. 32-81. Follow manufacturer's specifications.

If tire runout is excessive, check wheel runout. It may be possible to bring tire runout within specs by shifting the tire on the rim until the point of maximum tire runout is opposite the point of maximum wheel runout.

Wheel retaining lugs should be tightened to the proper torque and in the sequence shown in Fig. 32-82. This will prevent wheel or hub distortion. ALWAYS replace broken lug nuts or bolts with the correct size and type.

Runout may be checked by using a dial indicator or a special indicator. This is shown in Fig. 32-83.

The indicator stand must be heavy enough to hold the instrument in a fixed position. Raise the wheel and

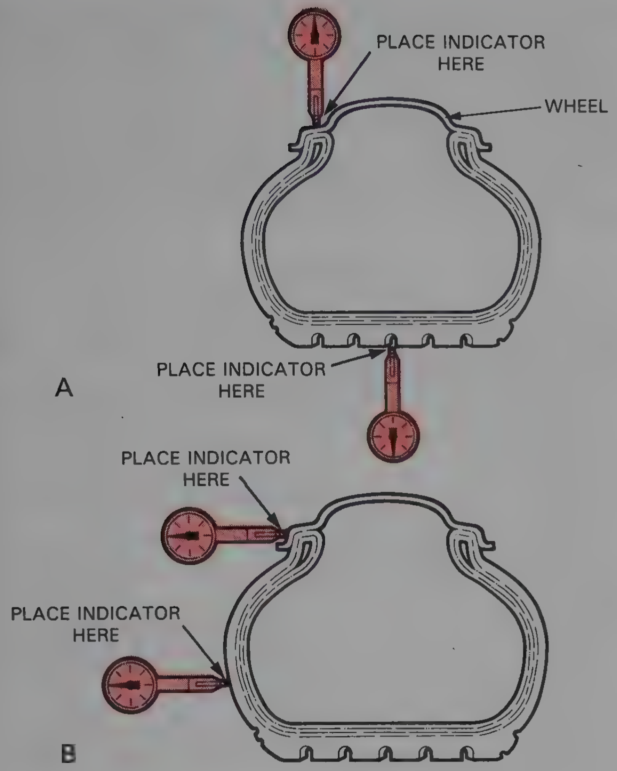

PLACE INDICATOR HERE
WHEEL
A
PLACE INDICATOR HERE
PLACE INDICATOR HERE
PLACE INDICATOR HERE
B

Fig. 32-81. A—Checking tire and rim radial runout. B—Checking lateral runout with a dial indicator. (B.F. Goodrich)

position the indicator. Slowly rotate wheel and note reading.

The tire must be warm to avoid any "flat spots" caused from standing for several hours.

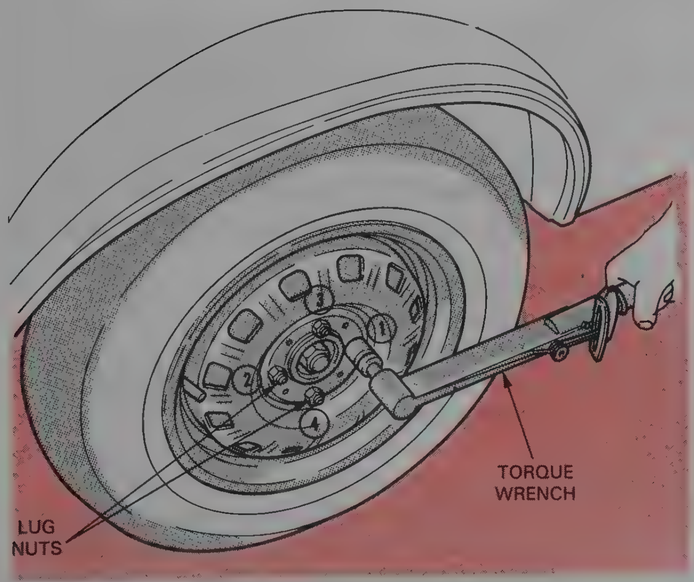

1
2
3
4
TORQUE WRENCH
LUG NUTS

Fig. 32-82. Wheel lugs should be tightened in recommended sequence. Wheel and hub surfaces must be clean. Tighten lugs to specified torque. (Chrysler)

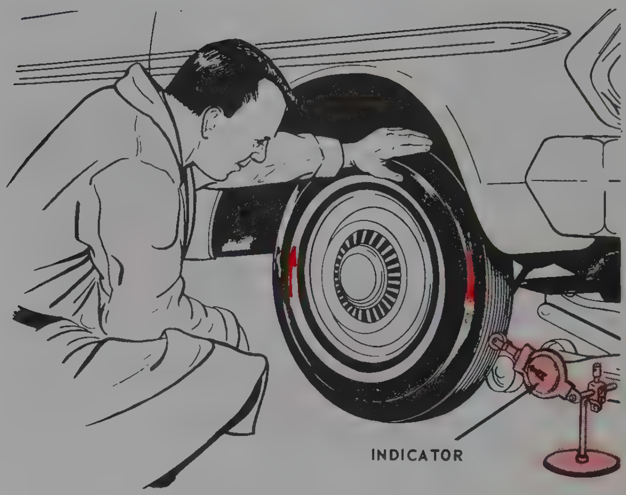


Fig. 32-83. Checking tire radial runout. Tire must be warm.

BALANCING

Good practice calls for both static and dynamic balance. The tire should be balanced statically first, and then balanced dynamically. Tire and wheel assemblies may be balanced on the car or off the car.

An "off-the-car" balancer is pictured in Fig. 32-84. Follow manufacturer's instructions. An "on-the-car" balancer is shown in Fig. 32-85.

CAUTION! Many front-wheel drive vehicles should have the front wheels spun by the engine, not with an on-car balancer. The suspension should not be allowed

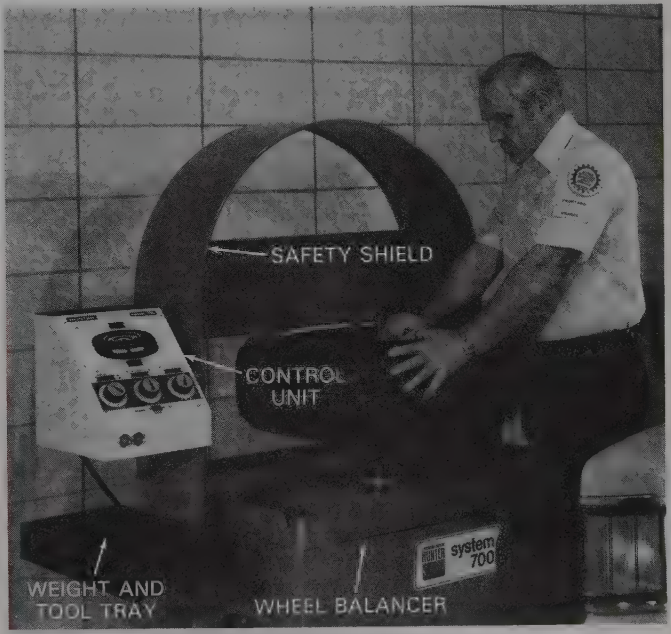

SAFETY SHIELD
CONTROL UNIT
HUNTER system 700
WEIGHT AND TOOL TRAY
WHEEL BALANCER

Fig. 32-84. Off-car wheel balancer. Note safety shield. Shield is pulled down to cover tire before unit is started. This stops stones and wheel weights which can fly off with lethal force. (Hunter)

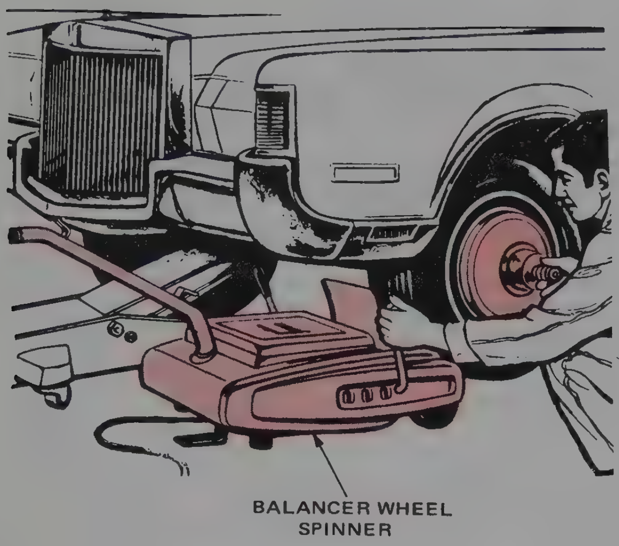


Fig. 32-85. "On-The-Car" wheel balancer. (Hunter)

to hang unsupported while spinning the wheels. Constant velocity universal joints, driving at extreme angles, can cause excessive vibrations and part damage.

Limit wheel speed to around 35 mph (56.3 km/h), as indicated on speedometer. REMEMBER! The speedometer indicates only one-half of the actual wheel speed when one wheel is spun and the other is stopped!

Extreme speed can cause the tire to disintegrate. It can also cause possible differential or transaxle damage.

BALANCING REAR WHEELS

The rear wheel and tire assemblies should also be balanced. When using an on-the-car balancer, on cars equipped with the traction type differential, raise both wheels from the floor. Remove one wheel. Replace a couple of the nuts to hold the drum in place. Balance the side with the wheel in place. Once that side is balanced, the other wheel should be installed and balanced. It is not necessary to remove the wheel already balanced.

When a standard differential is used, jack up one side only. Balance it. DO NOT TRY THIS ON THE TRACTION TYPE DIFFERENTIAL AS IT WILL MOVE THE CAR FORWARD. When balanced, lower the car to the floor. Raise the other wheel and balance. Make certain car is secure on jacks. Keep personnel out from in front of the car.

CAUTION! WHEN BALANCING THE REAR WHEELS, IF ONE WHEEL IS ON THE FLOOR AND THE OTHER IS FREE TO TURN, REVOLVING WHEEL WILL TURN TWICE AS FAST AS THE SPEEDOMETER INDICATES. DO NOT EXCEED A SPEEDOMETER READING OF AROUND 40 MPH (64 km/h). THIS WILL PRODUCE A WHEEL SPEED OF ABOUT 80 MPH (129 km/h).

With the traction type differential setup (both sides free of floor), wheel speed will be that indicated by the speedometer.

Use quality equipment in top shape. Follow manufacturer's instructions. Always clean the wheel of mud and grease, and pick out rocks stuck in the tread before balancing.

SUMMARY

Wheels must be properly aligned to produce good steering, handling, and wear.

Alignment angles are caster, camber, toe-in, steering axis inclination, and toe-out on turns. Wheels must also track correctly.

Before checking wheel alignment, make the recommended prealignment inspections.

Car curb weight and height must be as specified before alignment checks.

Alignment spacers are sometimes used to obtain exact curb height. Where spacers are not employed, bounce car before making checks.

Caster (tilting top ball joint forward or backward) may be specified as negative (tipped to front) or positive (tipped to rear).

Camber (tilting top of wheel in or out) may be specified as negative (tipped inward) or positive (tipped outward).

Toe-in (front of tires closer together than rear) compensates for looseness in the steering system that tends to allow wheels to open (toe-out) at the front.

Steering axis inclination (tipping top ball joint inward) places the load nearer the tire-road contact area. This makes for easier steering and reduces the need for excessive camber. Steering axis inclination is not adjustable.

More positive camber may be adjusted into the left front wheel to compensate for road camber or crown. Caster can also be varied in the left wheel to handle the normal road crown.

Never use heat on suspension or steering parts. Avoid bending. If bending MUST be done, bend COLD and limit amount of bending to 5 deg. Never try welding parts.

When front wheels are straight ahead, they must be at the same angle to the centerline of the car. The steering gear must be at midpoint in its travel. The steering wheel spokes should be in the proper position.

When replacing a steering wheel, make certain it is properly aligned. Torque retaining nut and use locking compound to prevent loosening.

Toe-out on turns allows the inner wheel to turn more sharply than the outer so that it may move about a smaller radius without the tires scrubbing. Toe-out on turns is determined by the angle of the steering arms. Replace the arms if bent.

Front wheel bearings may be of ball or roller design.

Clean, pack, and adjust wheel bearings on a mileage schedule as recommended by the manufacturer.

Use wheel bearing grease. Pack the bearings full. Coat the spindle and dust cap with a thin coat. Pack the hub grease recess.

Adjust roller bearings to produce zero to .003 in. (0.076 mm) end play. Ball bearings should have a mild preload.

Use a new cotter pin or staked nut following adjustment. Be sure to bend cotter pin ends open so that pin is TIGHT. A loose cotter pin can break. Always check to make sure the safety washer and nut lock (if used) are in place.

Use a new grease seal when repacking wheel bearings. Keep grease off of brake linings, drums, pads, and rotors.

When a bearing must be replaced, replace bearing outer race and inner race. Never change bearings from one wheel to another. Do not mix wheel bearing lubricants.

Tire size is determined by diameter across beads when mounted, and cross-sectional width, Fig. 32-86. Wheel rim size is determined by flange height, width between flanges, and the diameter across the rim.

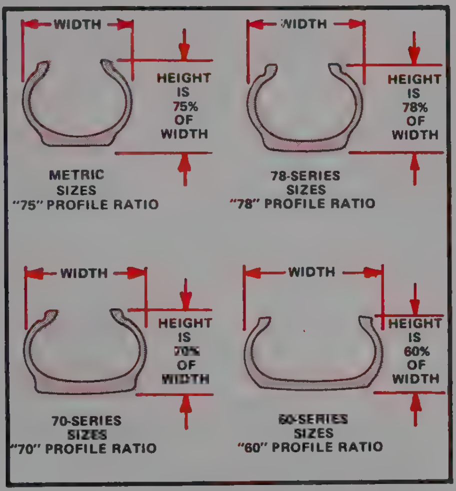

WIDTH
HEIGHT IS 75% OF WIDTH
METRIC SIZES "75" PROFILE RATIO
WIDTH
HEIGHT IS 78% OF WIDTH
78-SERIES SIZES "78" PROFILE RATIO
WIDTH
HEIGHT IS 70% OF WIDTH
70-SERIES SIZES "70" PROFILE RATIO
WIDTH
HEIGHT IS 60% OF WIDTH
60-SERIES SIZES "60" PROFILE RATIO

Fig. 32-86. Various tire size and profile ratios. (American Motors)

Rayon, nylon, polyester, Fiberglas, arimid, and steel are widely used in tire manufacture. Tire fabric (cord) may be applied in criss-cross, radial, or a combination of these two patterns.

Tire pressure must be correct. Add 4 psi (25 kPa) to recommended amount for high speed driving (where allowed). Check pressure when cold. See Fig. 32-87.

INFLATION PRESSURE CONVERSION CHART (KILOPASCALS TO PSI)

kPa	psi	kPa	psi
140	20	215	31
145	21	220	32
155	22	230	33
160	23	235	34
165	24	240	35
170	25	250	36
180	26	275	40
185	27	310	45
190	28	345	50
200	29	380	55
205	30	415	60

Conversion: 6.9 kPa = 1 psi

Fig. 32-87. Metric-to-English tire pressures. (Pontiac)

Rotate tires about every 5,000 miles (8 000 km).

Use rubber lubricant when demounting or mounting tires. Clean rim and check for dents, burrs, and cracks before mounting tire.

Punctures often can be repaired by inserting a rubber plug in the hole, either outside-in or inside-out. Demounting the tire is best.

When seating beads against rim flanges, stand back and do not exceed 40 psi (276 kPa) pressure. Reduce to normal running pressure when seated.

Tire wear patterns often indicate the cause of wear.

Tires are graded for temperature resistance, traction, and tread wear by Uniform Tire Quality Grading System (UTQGS).

Both front and back wheel and tire assemblies must be balanced. Balance statically and dynamically. Clean wheel and tire before balancing. Check tire radial and lateral runout before balancing. Check wheel lug torque. Tighten in proper sequence.

On-car or off-car balancing equipment may be used. Some front-wheel drive vehicles should use the engine to spin the tires when using an on-car balancer.

When balancing back wheels with on-car equipment, do not exceed 35-40 mph (56.3-64.4 km/h) speedometer reading.

On-car balancing, in cases where a traction differential is used, requires raising both sides. Remove one wheel. Balance the remaining one. Replace the first wheel and then balance it.

Static balance should be corrected first, then dynamic balance.

PROBLEM DIAGNOSIS

PROBLEM: WHEEL TRAMP

	Possible Cause		Correction
1.	Brake drum, rotor, wheel, or tire out of static balance.	1.	Balance assembly statically and dynamically.
2.	Wheel or tire out-of-round (excessive radial runout).	2.	Change tire position on wheel or discard tire or wheel as needed.
3.	Defective shock absorbers.	3.	Replace shocks.
4.	Bulge on tire.	4.	Replace tire.
5.	Defective front stabilizer.	5.	Replace stabilizer.
6.	Loose or worn wheel bearings.	6.	Adjust or replace bearings.
7.	Defective MacPherson strut.	7.	Replace strut.

PROBLEM: WHEEL SHIMMY

	Possible Cause		Correction
1.	Wheel and tire assembly out of dynamic balance.	1.	Balance assembly statically and dynamically.
2.	Tire pressure uneven.	2.	Inflate both front tires to same pressure.
3.	Worn or loose front wheel bearings.	3.	Adjust or replace bearings.
4.	Defective shock absorbers.	4.	Replace shocks.
5.	Improper or uneven caster.	5.	Adjust caster angle.
6.	Excessive tire or wheel runout.	6.	Correct by moving tire on rim or replace defective unit.
7.	Abnormally worn tires.	7.	Move to rear if still serviceable.
8.	Improper toe-in.	8.	Adjust to specifications.
9.	Defective stabilizer bar.	9.	Replace stabilizer.
10.	Tire pressure too low.	10.	Inflate tires to correct pressure.
11.	Loose wheel lugs.	11.	Tighten lugs.
12.	Front end alignment out.	12.	Align front end.
13.	Bent wheel.	13.	Replace wheel.

PROBLEM: POOR RECOVERY FOLLOWING TURNS AND/OR HARD STEERING

	Possible Cause		Correction
1.	Low tire pressure.	1.	Inflate to proper pressure.
2.	Lack of lubrication.	2.	Lubricate steering system.
3.	Front wheel alignment.	3.	Align properly.
4.	Bent spindle assembly.	4.	Replace spindle assembly.

PROBLEM: CAR PULLS TO ONE SIDE

	Possible Cause		Correction
1.	Uneven tire pressure.	1.	Inflate both front tires to same pressure.
2.	Improper toe-in.	2.	Adjust toe-in to specifications.
3.	Incorrect or uneven caster.	3.	Adjust caster angle.
4.	Incorrect or uneven camber.	4.	Adjust camber angle.
5.	Improper rear wheel tracking.	5.	Align rear axle assembly.
6.	Tires not same size.	6.	Install same size tires on both sides.
7.	Bent spindle assembly.	7.	Replace spindle.
8.	Worn or improperly adjusted wheel bearings.	8.	Adjust or replace bearings.
9.	Dragging brakes.	9.	Adjust brakes.

PROBLEM: CAR WANDERS FROM SIDE TO SIDE

	Possible Cause		Correction
1.	Low or uneven tire pressure.	1.	Inflate tires to recommended pressure.
2.	Toe-in incorrect.	2.	Adjust toe-in.
3.	Improper caster.	3.	Adjust caster angle.
4.	Improper camber.	4.	Adjust camber angle.
5.	Worn or improperly adjusted front wheel bearings.	5.	Replace or adjust wheel bearings.
6.	Vehicle overloaded or loaded too much on one side.	6.	Instruct owner regarding load limits.
7.	Bent spindle assembly.	7.	Replace spindle.

PROBLEM: TIRE SQUEAL ON CORNERS

Possible Cause	Correction
1. Low tire pressure.	1. Inflate to recommended pressure.
2. Toe-out on turns incorrect.	2. Replace bent steering arm.
3. Excessive cornering speed.	3. Instruct owner.
4. Bent spindle assembly.	4. Replace spindle.
5. Improper front end alignment.	5. Align front wheels.

PROBLEM: LOOSE ERRATIC STEERING

Possible Cause	Correction
1. Loose front wheel bearings.	1. Replace or adjust.
2. Loose wheel lugs.	2. Tighten lugs.
3. Wheel out of balance.	3. Balance wheel assembly.

PROBLEM: HARD RIDING

Possible Cause	Correction
1. Excessive tire pressure.	1. Reduce pressure to specifications.
2. Improper tire size.	2. Install correct size.
3. Excessive number of plies in tires.	3. Install recommended tires (usually) two or four-ply.

PROBLEM: IMPROPER WHEEL TRACKING

Possible Cause	Correction
1. Frame sprung.	1. Straighten.
2. Rear axle housing sprung.	2. Replace or straighten housing.
3. Broken leaf spring.	3. Replace spring.
4. Broken spring center bolt. Spring shifted on axle housing.	4. Install new spring center bolt.

PROBLEM: NOISE FROM FRONT OR REAR WHEELS

Possible Cause	Correction
1. Wheel lugs loose.	1. Tighten lugs.
2. Defective wheel bearings.	2. Replace bearings.
3. Loose wheel bearings.	3. Adjust wheel bearings.
4. Lack of lubrication.	4. Lubricate bearings.
5. Lump or bulge on tire tread.	5. Replace tire.
6. Rock stuck in tire tread.	6. Remove rock.
7. Cracked wheel.	7. Replace wheel.
8. Wheel hub loose on axle taper (where used).	8. Inspect and tighten.

PROBLEM: TIRES LOSE AIR

Possible Cause	Correction
1. Puncture.	1. Repair puncture.
2. Bent, dirty, or rusty rim flanges.	2. Clean or replace wheel.
3. Loose wheel-rim rivets.	3. Peen rivets.
4. Leaking valve core or stem.	4. Replace as needed.
5. Striking curbs with excessive force.	5. Instruct driver.
6. Flaw in tire casing.	6. Repair or replace tire.
7. Excessive cornering speed especially with low tire pressure.	7. Instruct driver.

PROBLEM: TIRE WEARS IN CENTER

Possible Cause	Correction
1. Excessive pressure.	1. Reduce tire pressure to specifications.

PROBLEM: TIRE WEARS ON ONE EDGE

Possible Cause	Correction
1. Improper camber.	1. Align camber angle.
2. High speed cornering.	2. Instruct owner.

PROBLEM: TIRE WEARS ON BOTH SIDES

Possible Cause	Correction
1. Low pressure.	1. Inflate tires to specifications.
2. Overloading car.	2. Instruct owner.

PROBLEM: TIRE SCUFFING OR FEATHEREDGING

Possible Cause	Correction
1. Excessive toe-out (inside edges).	1. Correct toe-out.
2. Excessive toe-in (outside edges).	2. Correct toe-in.
3. Excessive cornering speed.	3. Instruct driver.
4. Improper tire pressure.	4. Inflate tires to specifications.
5. Wheel shimmy.	5. Balance wheels statically and dynamically.
6. Improper toe-out on turns.	6. Replace bent steering arm.
7. Excessive runout.	7. Correct or replace tire or wheel.
8. Uneven camber.	8. Adjust camber angle.
9. Bent spindle assembly.	9. Replace spindle.

PROBLEM: TIRE CUPPING

Possible Cause	Correction
1. Uneven camber.	1. Correct camber angle.
2. Bent spindle assembly.	2. Replace spindle.
3. Improper toe-in.	3. Adjust toe-in.
4. Improper tire pressure.	4. Inflate tires to specifications.
5. Excessive runout.	5. Correct or replace wheel or tire.
6. Wheel and tire assembly out of balance.	6. Balance both statically and dynamically.
7. Worn or improperly adjusted wheel bearings.	7. Replace or adjust wheel bearings.
8. Grabby brakes.	8. Repair brakes.

PROBLEM: HEEL AND TOE WEAR

Possible Cause	Correction
1. Grabby brakes.	1. Repair brakes.
2. Heavy acceleration.	2. Instruct driver.

SPECIAL NOTE: Ease of steering, handling, and tire wear are also affected by the steering and suspension system. See chapter on steering and suspension service for problem diagnosis covering these areas.

KNOW THESE TERMS

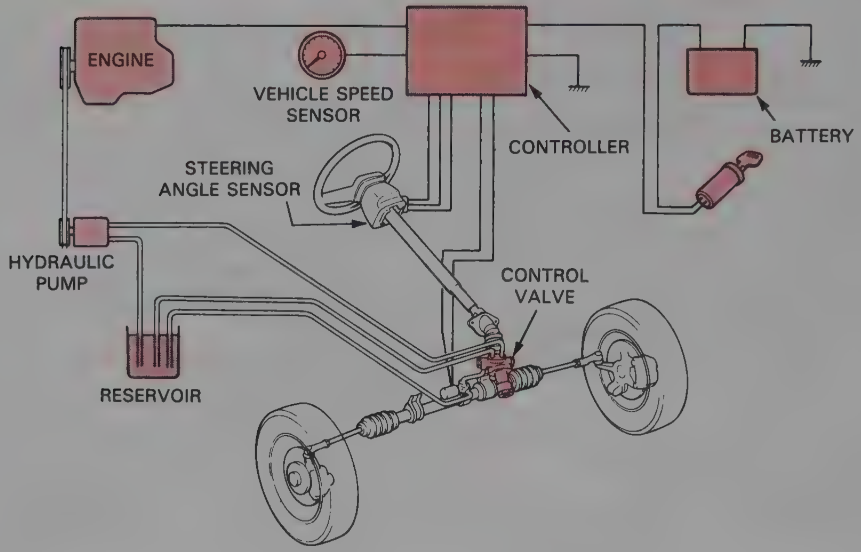
Caster, Camber, Toe-in, Toe-out, Steering axis inclination, Curb weight, Curb height, Lateral runout, Radial runout, Road crown, Trammel, Turning radius, Staked nut, Radial tire, Bearing cone creep, Cross-sectional height, Carcass ply, Tread ply, Bias tire, Bias-belted tire, Bead wire, Flange height, Bead expander, Hot patch, Static balance, Dynamic balance, Road camber, Cross-sectional width, Thrust angle, Setback.

QUIZ - Chapter 32

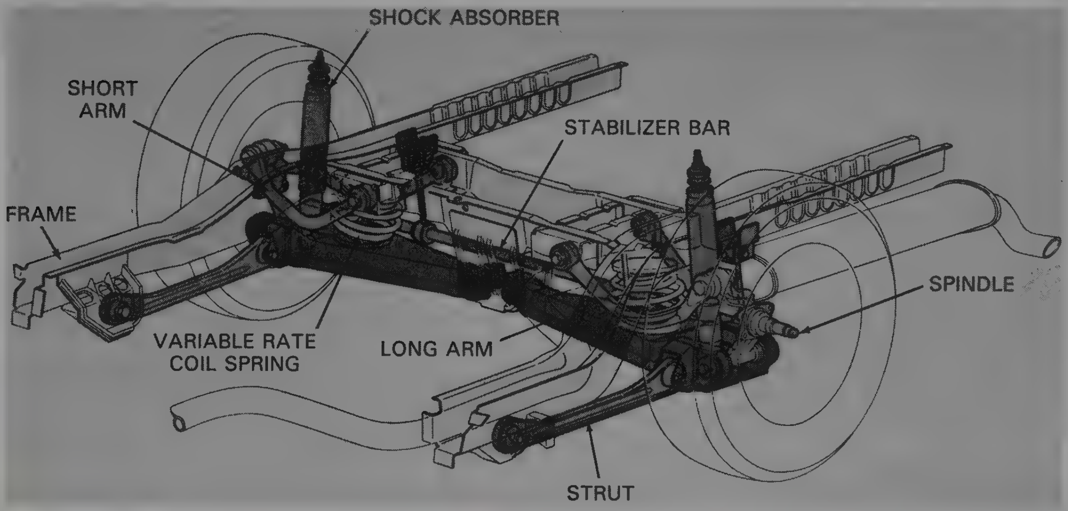
1. Caster angle involves tipping the top of the tire in or out. True or False?
2. Camber is changed by:
   a. Tipping the top ball joint in or out.
   b. Tipping the top of the tire in or out.
   c. Tipping both the ball joints inward.
   d. Tipping the top ball joint rearward.
3. Toe-in is required to offset toe-out on turns. True

or False?

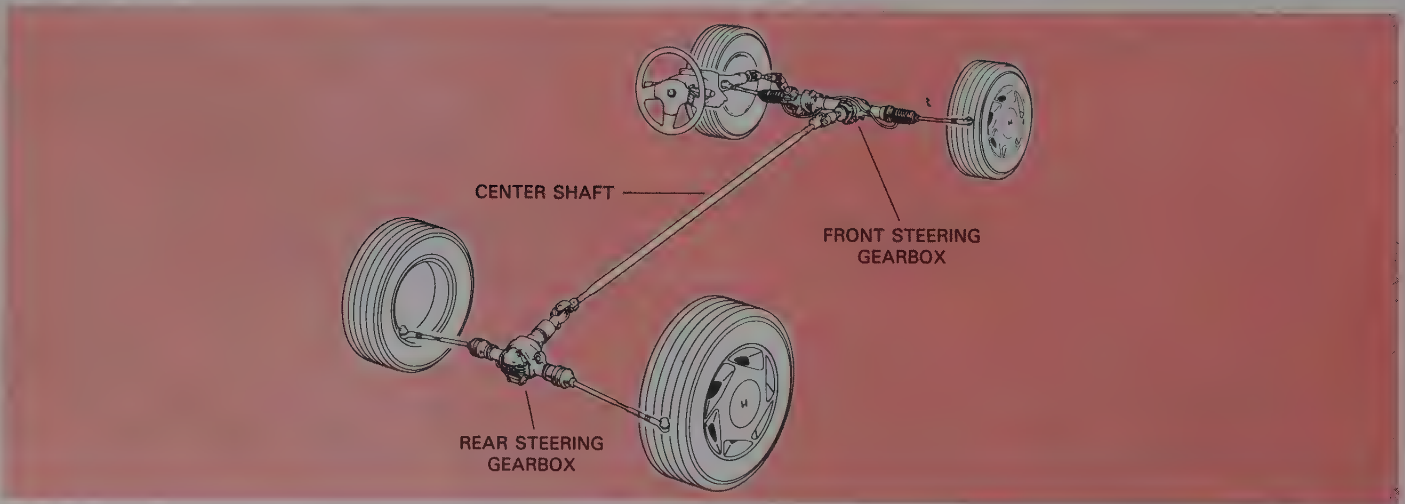
4. ____________ ____________ inclination reduces the need for excessive camber.
5. Toe-out on turns is adjusted by altering the length of the tie rods. True or False?
6. Proper front end alignment will guarantee correct rear wheel tracking. True or False?
7. Curb ____________ and ____________ should be as specified before aligning front wheels.
8. Vehicles using independent rear suspension systems require ____________ and ____________ checks at the rear wheels.
9. The pull created by road crown is best offset by:
   a. Running the left tire with less pressure.
   b. Putting a larger tire on the right.
   c. Introducing more positive camber in the left front wheel.
   d. Increasing toe-in.
10. ____________ compensates for the tendency of the front wheels to spread apart when driving.
11. Steering and suspension parts must never:
   a. Be bent beyond 5 deg.
   b. Be welded.
   c. Be heated.
   d. All three of the above.
12. In setting "center point steering," when the front wheels are straight ahead, they form the ________ angles with the ____________ of the vehicle. The steering gear is at the ____________ of travel and the steering wheel spokes are in the proper position.
13. Roller front wheel bearings should be adjusted to ____________ to ____________ end play.
14. Ball front wheel bearings should be adjusted to a mild ____________.
15. Pack hub completely full of grease. True or False?
16. Always replace the ____________ ____________ when packing or replacing wheel bearings.
17. The cotter pin (on front wheel adjusting nuts) may be used if it is not badly bent. True or False?
18. Before driving the dust cover into place:
   a. Apply a thin coat of grease to cover inside.
   b. Make certain cotter pin is in place.
   c. Make sure safety washer is in place.
   d. All of above.
19. A new outer bearing race may be used with the old inner race if in good condition. True or False?
20. Tire aspect ratio is determined by the relationship of tire cross-sectional ________ to ________.
21. For high speed driving, add about 4 psi (25 kPa) to the normal air pressure. True or False?
22. Better puncture repairs can be made by demounting the tire. True or False?
23. Rotate tires every ______________ miles or ______________ km.
24. ____________ ____________ should always be used to ease bead seating.
25. When inflating tire to seat beads, never exceed a pressure of ________ psi or ________ kPa.
26. Tire and wheel assemblies can explode with deadly force when attempting to seat beads by using excessive air pressure. True or False?
27. When seating tire beads, always ____________ ____________ from the tire.
28. Wheel tramp is caused by ______________ unbalance.
29. Wheel shimmy is caused by ______________ unbalance.
30. Tire radial runout should not exceed __________. Lateral runout should be kept within __________.
31. When using "on-the-car" equipment on the rear wheels, when one wheel contacts the floor and the other is rotating, never exceed a speedometer reading of ________ mph or ________ km/h.
32. Both front and rear tire and wheel assemblies should be balanced. True or False?
33. A tire in dynamic balance must also be in static balance. True or False?
34. Correct ____________ balance first and then ____________ balance.
35. A feathered edge on the tire tread would probably indicate improper ____________.
36. Uniform Tire Quality Grading System grades tires in three areas; they are: ______________ ______________, ______________, and ______________.
37. When rotating tires, you must:
   a. Include compact spare.
   b. Never include compact spare.
   c. Place compact spare in rear.
   d. Place compact spare in front.
38. Vehicles using a staked nut to adjust front wheel bearings must have new nuts installed each time one is removed. True or False?
39. Front-wheel drive vehicles should not have the front wheels spun in excess of ________ mph or ________ km/h or damage may result.


ENGINE
VEHICLE SPEED SENSOR
CONTROLLER
BATTERY
STEERING ANGLE SENSOR
HYDRAULIC PUMP
CONTROL VALVE
RESERVOIR

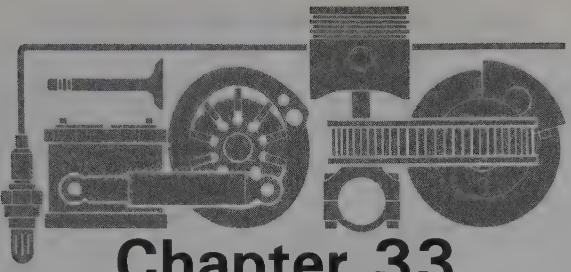
Overall view of a speed-sensitive, variable-assist rack and pinion. (Ford)


SHOCK ABSORBER
SHORT ARM
STABILIZER BAR
FRAME
SPINDLE
VARIABLE RATE COIL SPRING
LONG ARM
STRUT

Phantom view of an independent rear suspension. Note that upper control arm is shorter than lower control arm. Variable rate springs compress upon themselves allowing more wheel travel. (Ford)


CENTER SHAFT
FRONT STEERING GEARBOX
REAR STEERING GEARBOX

A four-wheel steering system. (Honda)



Chapter 33

STEERING, SUSPENSION SYSTEMS SERVICE

After studying this chapter, you will be able to:

☐ Explain the construction, operation, and service of manual steering systems.

☐ Describe the construction, operation, and service of power steering systems.

☐ Summarize the construction, operation, and service of front and rear suspension systems.

☐ Diagnose problems in steering and suspension systems.

CAUTION! When working on a vehicle equipped with a supplemental restraint system (air bag), always follow the manufacturer's service, repair, and handling instructions. Failure to do so can result in personal injury caused by the unintentional activation of the system. Neglecting the manufacturer's precautions can also prevent the air bag from inflating during an accident, resulting in occupant injury or death! For more information on air bag systems, see Chapter 24.

MANUAL STEERING SYSTEMS

Manual steering systems, though varying in design, all contain the same basic elements. They consist of a steering wheel, steering shaft, steering gear or rack and pinion assembly, pitman arm, linkage, steering arms, and spindle (steering knuckle) assemblies. A typical manual rack and pinion steering setup is illustrated in Fig. 33-1.

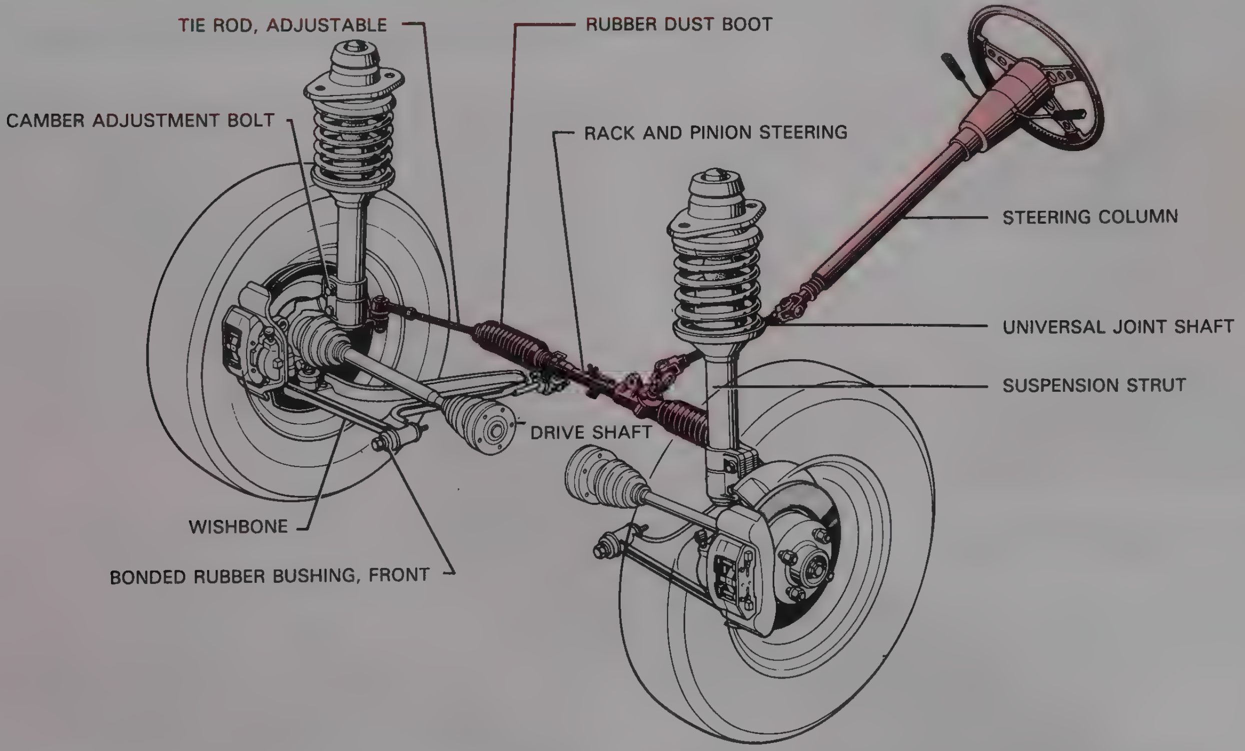

TIE ROD, ADJUSTABLE
RUBBER DUST BOOT
CAMBER ADJUSTMENT BOLT
RACK AND PINION STEERING
STEERING COLUMN
UNIVERSAL JOINT SHAFT
SUSPENSION STRUT
DRIVE SHAFT
WISHBONE
BONDED RUBBER BUSHING, FRONT

Fig. 33-1. One type of a manual rack and pinion steering setup, as used on a front-wheel drive vehicle. (Volkswagen)

STEERING SYSTEM INSPECTION

A periodic inspection of the steering system is important to safety as well as ease of handling. For details, see steering system inspection, in the section on power steering later in this chapter.

CHECKING MANUAL STEERING GEAR LUBRICANT LEVEL

Clean off the filler plug and surrounding area. Remove plug. Using a light, check the level of the gear lubricant. Fill to indicated level using recommended lubricant.

Steering gear lubricant should be relatively viscous (thick), yet should remain fluid at low temperatures so it will flow to all moving parts. Lubricant that is too thick can channel (gears cut a path through lubricant and lubricant fails to flow back against gear) and cause rapid gear wear and hard steering.

Multi-purpose gear lubricant is often specified. Occasionally, a soft, E.P. (extreme pressure) multi-purpose chassis lubricant is used as a manual steering gear lubricant.

Unless the oil is contaminated, there is no need for periodic steering gear oil changes.

Note steering gearbox filler plug and lubricant level pictured in Fig. 33-2.

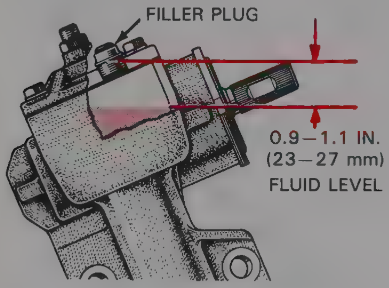


Fig. 33-2. Maintain steering gear lubricant at maker's specified level. (Toyota)

Some steering gears do not have regular filler plugs. One such gear is shown in Fig. 33-3. In this type gear, remove the two cover attaching bolts. Fill gearbox at A until lubricant appears at B.

MANUAL STEERING GEAR

The manual steering gear in popular use today employs the recirculating ball worm and nut design. The gear ratio averages about 24 to 1 (twenty-four turns of steering or worm shaft to one complete turn of pitman shaft).

The gearbox is attached to the frame and is usually connected to the steering shaft by a shock absorbing universal joint. One form of the recirculating ball worm and nut steering gear is shown in Fig. 33-4.

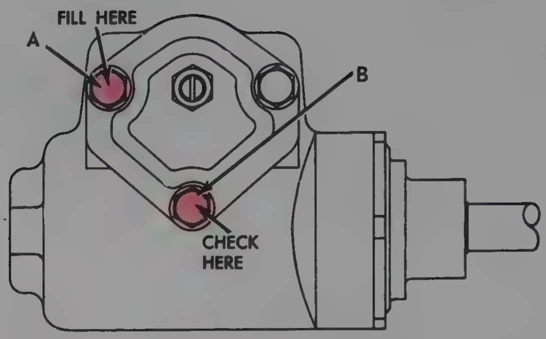


Fig. 33-3. Remove gear cover fasteners to check and adjust lubricant level. (Chevrolet)

A different recirculating ball worm and nut steering gear is illustrated in Fig. 33-5. Note how the pitman arm is attached to the pitman shaft (cross shaft, sector shaft, etc.). A rack and pinion gearbox is pictured in Fig. 33-6.

MANUAL STEERING GEAR ADJUSTMENTS

There are two adjustments on the majority of steering gears: WORM BEARING PRELOAD AND OVER-CENTER ADJUSTMENT (clearance between ball nut and sector teeth with gear in center of travel).

MAKE THE WORM BEARING PRELOAD ADJUSTMENT FIRST.

WORM BEARING PRELOAD ADJUSTMENT

To make the worm bearing preload adjustment, remove the pitman arm from the pitman shaft (see Pitman Arm Removal later in this chapter).

Loosen the pitman shaft adjusting screw locknut. Back off the adjusting screw, two or three turns. See Figs. 33-4, 33-5, and 33-7.

Remove any load that may be imposed on the worm gear. When the ball nut and pitman sector teeth are meshed in the center, mesh is tightest. The loosest is in the extreme right or left positions. To remove any load, turn the wheel the specified number of turns (generally about 1-1/2 turns) away from the center position.

Be careful. When the pitman arm is disconnected, it is possible to damage the ball guides if the steering wheel is turned rapidly until it strikes the stops. If turning to extreme left or right, do so slowly and gently.

Remove the ornamental cap from the end of the steering column. Attach an inch pound torque wrench to the steering wheel retaining nut. Move the wrench in a direction that causes the wheel to turn toward the center position. Note the reading when the wheel is moving the specified distance either side of center.

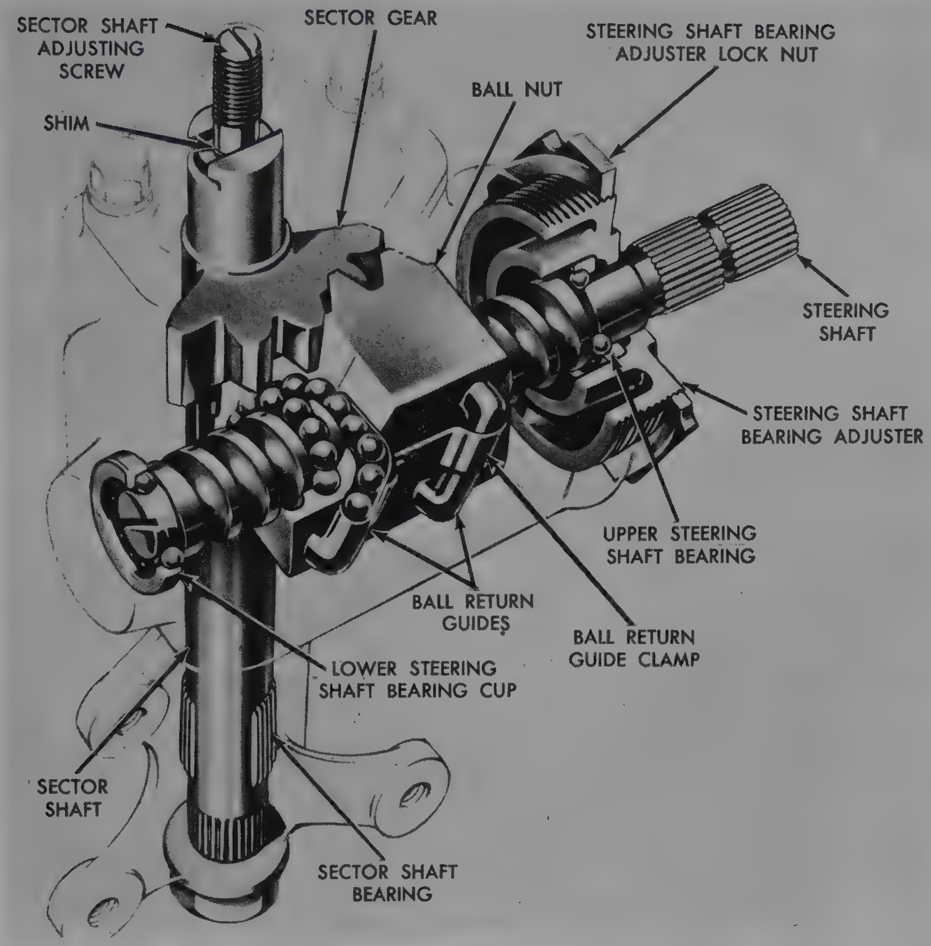

SECTOR SHAFT ADJUSTING SCREW
SECTOR GEAR
STEERING SHAFT BEARING ADJUSTER LOCK NUT
BALL NUT
SHIM
STEERING SHAFT
STEERING SHAFT BEARING ADJUSTER
UPPER STEERING SHAFT BEARING
BALL RETURN GUIDES
BALL RETURN GUIDE CLAMP
LOWER STEERING SHAFT BEARING CUP
SECTOR SHAFT
SECTOR SHAFT BEARING

Fig. 33-4. One form of recirculating ball worm and nut steering gear. As worm shaft (steering shaft) is turned, ball nut forces sector gear to rotate sector (pitman) shaft. (Ford)

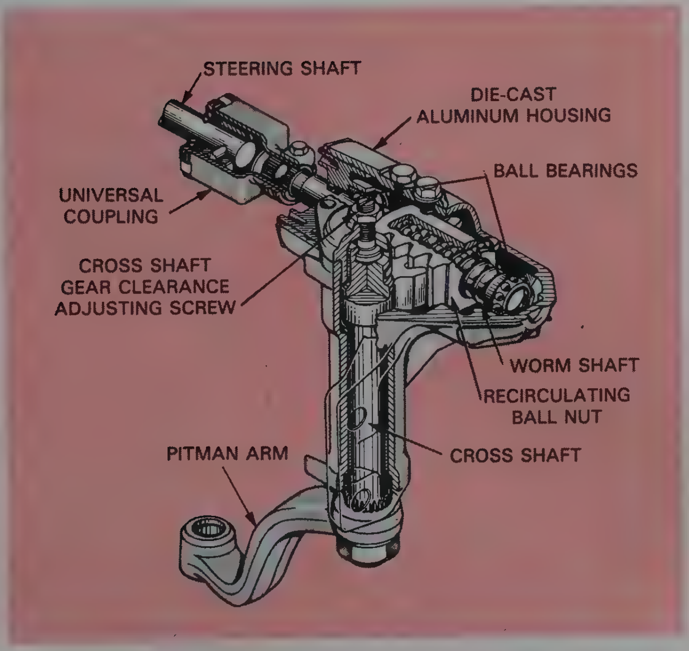

STEERING SHAFT
DIE-CAST ALUMINUM HOUSING
BALL BEARINGS
UNIVERSAL COUPLING
CROSS SHAFT GEAR CLEARANCE ADJUSTING SCREW
WORM SHAFT
RECIRCULATING BALL NUT
PITMAN ARM
CROSS SHAFT

Fig. 33-5. Another design of recirculating ball worm and nut steering gear. (Plymouth)

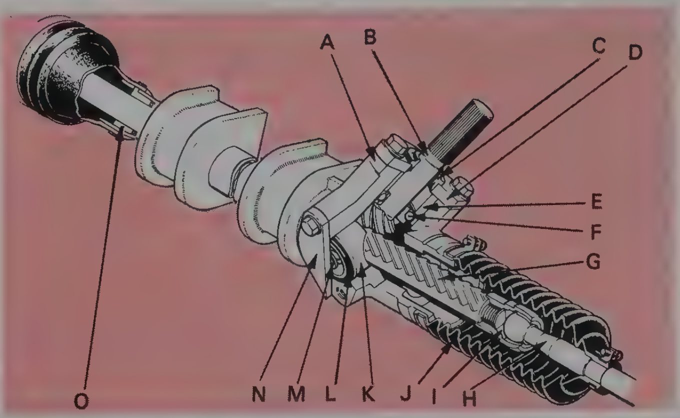

A
B
C
D
E
F
G
O
N
M
L
K
J
I
H

Fig. 33-6. Cutaway view of a manual rack and pinion steering gear unit. A—Housing. B—Pinion. C—Seal. D—Pinion cover. E—Spacer sleeve. F—Upper pinion bearing. G—Rack. H—Steering rod. I—Inner ball joint. J—Rubber bellows. K—Pretensioning piston. L—O-ring. M—Spring. N—Cover. O—Bushing. (Volvo)

Compare with factory specifications, Fig. 33-8.

If adjustment is required, loosen the worm shaft bearing adjuster locknut. Turn bearing adjuster as

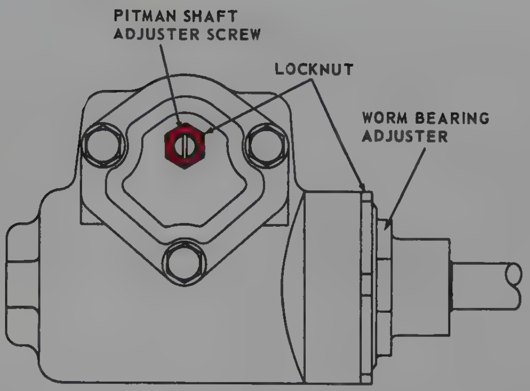


Fig. 33-7. Loosen locknut and unscrew pitman shaft adjuster screw. (Chevrolet)

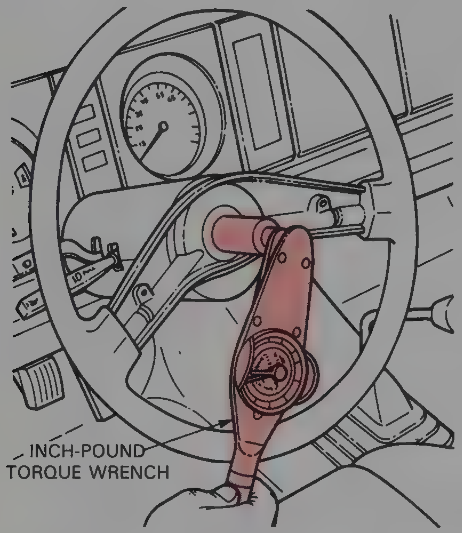


Fig. 33-8. Using an inch-pound torque wrench to check worm shaft preload. Try to maintain a constant turning speed with wrench for most accurate reading. (Ford)

required to produce the specified worm shaft bearing preload.

Tighten locknut SECURELY and recheck turning torque, Fig. 33-9.

The wheel should turn freely from stop to stop without binding or roughness. If roughness is present, worm bearings may be defective and must be replaced. Binding may be caused by gearbox and steering column misalignment. When worm shaft bearing preload adjustment is complete, proceed with the over-center mesh adjustment.

PITMAN SHAFT GEAR OVER-CENTER ADJUSTMENT

To make the over-center adjustment (depth of mesh with gear at the center of its travel), torque the cover fasteners to specifications. This draws the lash adjuster inward.

Turn the steering wheel from extreme left to extreme right while counting the number of turns. Do not bang against stops. Turn the wheel back to the left one-half this number of turns. This places the worm and sector gears in the center of their travel.

Turn the pitman shaft lash adjuster screw clockwise until all play is removed. Tighten adjuster screw locknut.

With an inch-pound torque wrench, Fig. 33-8, check the pull required to move the wheel through the center high point. To do this, center the gear. Move the wheel an additional one-half turn to left. Then pull the wheel one full turn to the right. Note highest reading. Compare with specifications.

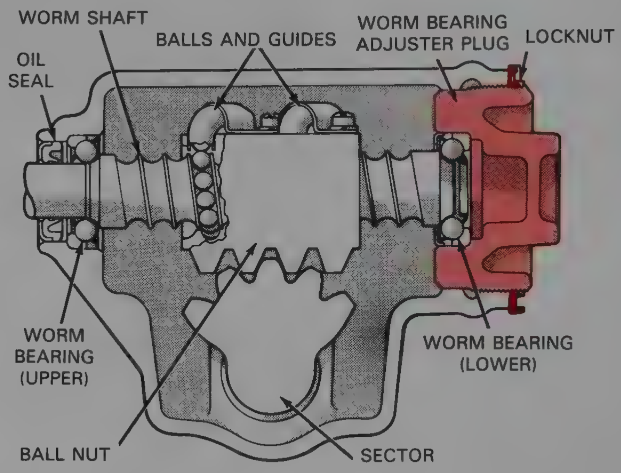


Fig. 33-9. After loosening locknut, worm shaft bearing adjuster plug is turned until bearing preload is set to specifications. (Chrysler)

Loosen the locknut and move the pitman shaft lash adjuster screw as required. Tighten locknut securely and recheck.

The pull required represents the original worm preload PLUS the over-center load, Fig. 33-10.

Note how the clearance between the pitman shaft sector gear teeth and the ball nut teeth can be reduced by forcing the pitman shaft inward with the lash adjuster screw. The tapered ball nut teeth make this possible, Fig. 33-11.

Remember! Adjust the worm shaft bearing preload FIRST — with the gear in an off-center position. Make the over-center adjustment LAST — with the gear in the CENTER of its travel.

A slight amount of play between the sector and ball nut teeth, in the extreme right or left turn position, is NORMAL. Do not try to adjust it out because the over-center adjustment will become too tight.

Some manufacturers specify the use of a spring scale on the steering wheel in place of a torque wrench. If a scale is used, it must be ACCURATE. Attach as shown in Fig. 33-12. Pull on the scale. Keep it in line with the direction of rim travel.

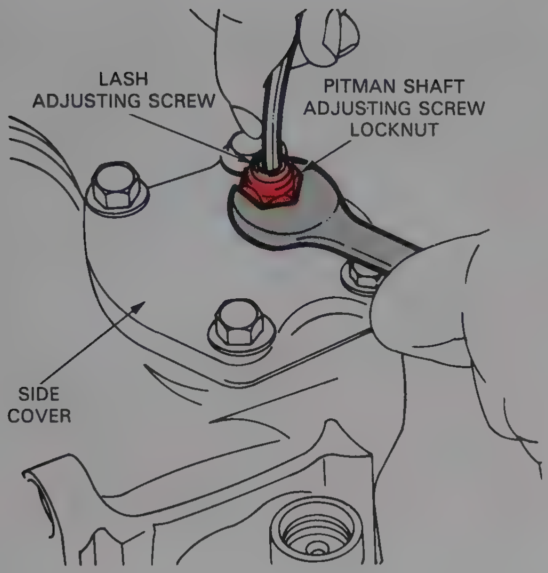

LASH
ADJUSTING SCREW
PITMAN SHAFT
ADJUSTING SCREW
LOCKNUT
SIDE
COVER

Fig. 33-10. Turning pitman shaft lash adjusting screw. Note! Some locknuts have left-hand threads. (Jeep)

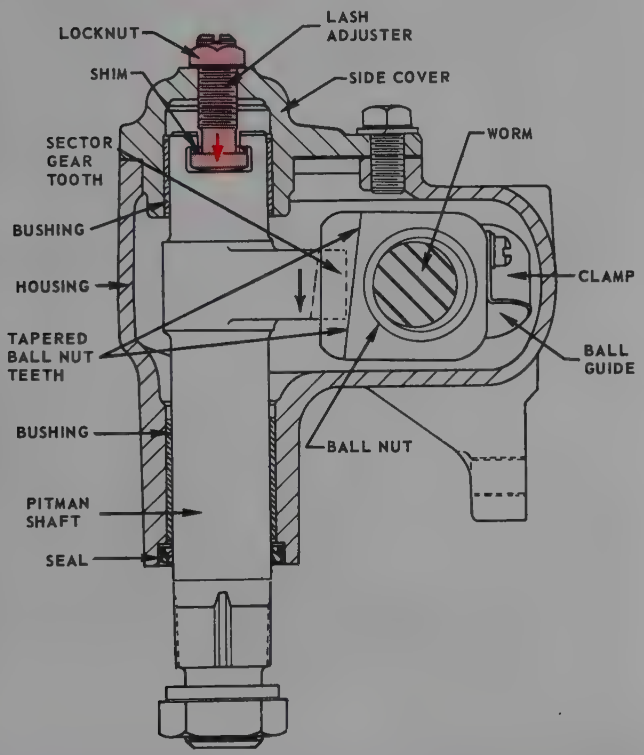

LOCKNUT
LASH
ADJUSTER
SHIM
SIDE COVER
SECTOR
GEAR
TOOTH
WORM
BUSHING
HOUSING
CLAMP
TAPERED
BALL NUT
TEETH
BALL
GUIDE
BUSHING
BALL NUT
PITMAN
SHAFT
SEAL

Fig. 33-11. When lash adjuster screw forces pitman shaft inward, pitman sector gear moves into closer mesh with tapered ball nut teeth. (Buick)

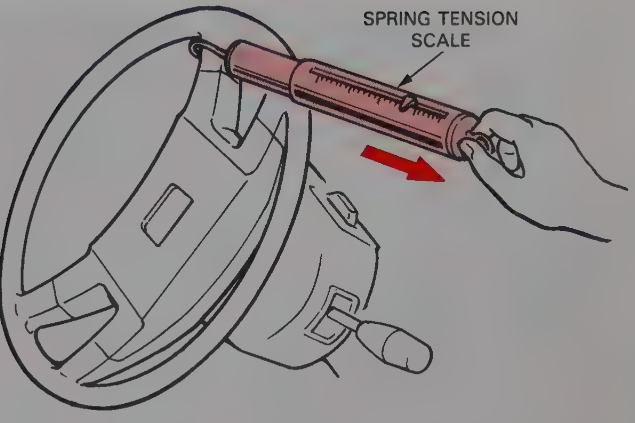

SPRING TENSION
SCALE

Fig. 33-12. Checking steering gear adjustment with an accurate spring tension scale. (Honda)

MANUAL STEERING GEAR OVERHAUL — BALL NUT

Remove pitman arm. Remove worm shaft-to-steering shaft universal joint. Remove gear housing-to-frame fasteners. Pull gear housing. (Some cars require removal of steering wheel, entire steering column, etc.) Clean the exterior of the housing thoroughly.

Remove the cover. Disconnect pitman (sector) shaft adjusting screw from pitman (sector) shaft. Do not lose the shim on the adjusting screw. Pull the pitman shaft from the housing. Fig. 33-13 shows the various parts of the pitman shaft and adjustment assembly.

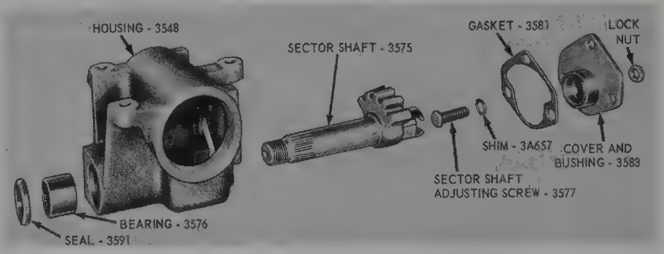

HOUSING - 3548
SECTOR SHAFT - 3575
GASKET - 3581
LOCK
NUT
SHIM - 3A657
COVER AND
BUSHING - 3583
SECTOR SHAFT
ADJUSTING SCREW - 3577
BEARING - 3576
SEAL - 3591

Fig. 33-13. Gear housing and pitman shaft assembly. (Ford)

Center sector and ball. Loosen worm bearing adjuster lock and remove adjuster, worm (steering) shaft, and ball nut assembly. When withdrawing worm shaft and ball nut assembly, hold the assembly in a horizontal position. This will prevent the ball nut from spiraling down the worm and causing possible damage to the ball return guides.

Remove the ball return guide clamp and guides from the ball nut. Turn the ball nut downward. Oscillate the worm shaft until all of the balls have dropped into a clean container. BE CAREFUL NOT TO LOSE ANY.

When all the balls are out, the ball nut will slide off the worm shaft.

The worm shaft (steering shaft) assembly is shown in Fig. 33-14. Note arrangement of parts.

Remove bearing cups. Some bearing cups are serviced as an assembly with the adjuster.

The lower bearing cup in the gearbox in Fig. 33-15 is removed by striking the gearbox sharply against a

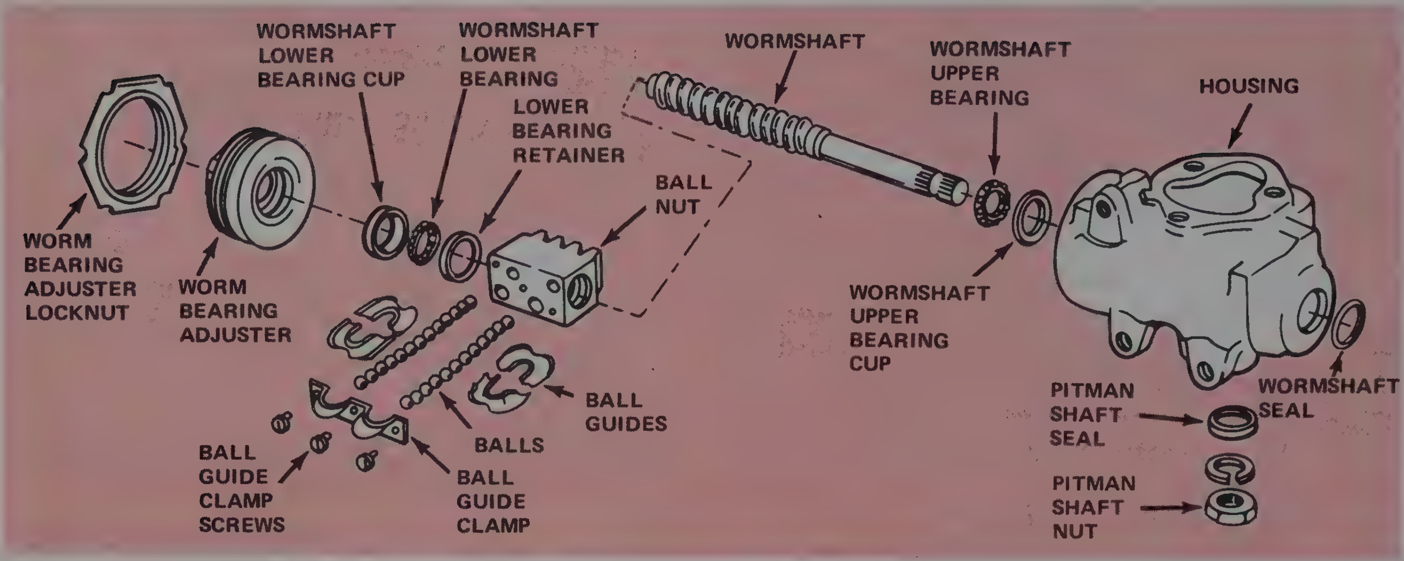

WORMSHAFT LOWER BEARING CUP
WORMSHAFT LOWER BEARING
LOWER BEARING RETAINER
WORMSHAFT
WORMSHAFT UPPER BEARING
HOUSING
BALL NUT
WORM BEARING ADJUSTER LOCKNUT
WORM BEARING ADJUSTER
WORMSHAFT UPPER BEARING CUP
PITMAN SHAFT SEAL
WORMSHAFT SEAL
BALL GUIDES
BALLS
BALL GUIDE CLAMP SCREWS
BALL GUIDE CLAMP
PITMAN SHAFT NUT

Fig. 33-14. Exploded view of gear housing, ball nut, and worm shaft assembly. (AMC)

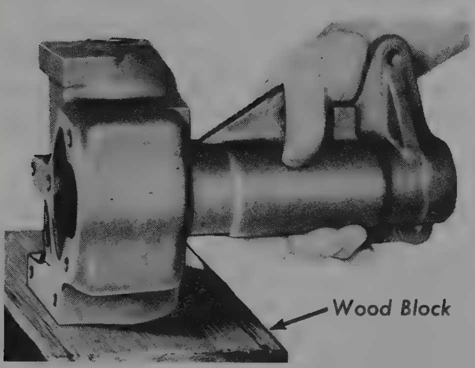


Fig. 33-15. Removing lower worm bearing cup by striking gear housing against block of wood.

block of wood. Press out pitman shaft bushings or bearings and seal. See Fig. 33-16.

Clean all parts. Inspect bearings, cups, and worm shaft bearing surfaces for pitting, galling, and wear. Check worm shaft and ball nut bearing surfaces.

Check ball nut and sector teeth. Inspect pitman shaft for wear, scoring, and galling.

Replace parts as needed. THE STEERING GEAR CONDITION IS VERY IMPORTANT TO THE SAFE OPERATION OF THE STEERING SYSTEM. REPLACE ALL PARTS SHOWING SIGNS OF DAMAGE OR NOTICEABLE WEAR. USE A CRACK DETECTOR ON THE PITMAN SHAFT AND SECTOR, BALL NUT TEETH, AND WORM.

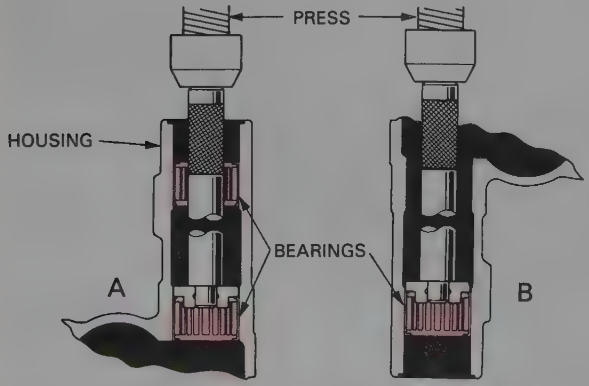

PRESS
HOUSING
BEARINGS
A
B

Fig. 33-16. Pressing out pitman shaft bearings. A—Pressing out inside bearing. B—Pressing out outer bearing. Be careful! (Toyota)

INSTALL BALL NUT CORRECTLY

Slide the ball nut onto the worm shaft so that, when the assembly is placed in the gear housing, the deep side of the nut teeth will face the cover.

On the assembly in Fig. 33-17, when the worm shaft splined end is to the right, the narrow end of the nut tooth taper (deep side of teeth) should face down. When installed, the deep side of the teeth will then face the cover.

Align ball grooves in worm shaft with grooves in ball

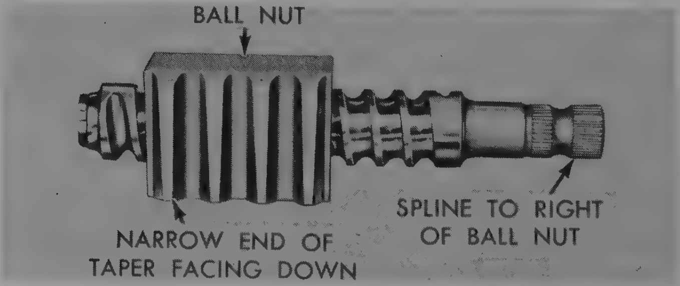

BALL NUT
SPLINE TO RIGHT OF BALL NUT
NARROW END OF TAPER FACING DOWN

Fig. 33-17. Ball nut must be correctly assembled to worm shaft.

nut by sighting through ball guide openings.

Using thick grease to hold them in place, insert the specified number of balls in the ball guides. Place one-half of the remaining number of balls in each ball circuit. Oscillate (DO NOT ROTATE) the worm shaft to facilitate ball insertion.

Install ball return guides in their respective holes. Install ball guide clamp and torque screws. Press in new pitman shaft bearings (or bushings) and new seals.

Install bearing cups, ball bearings, worm shaft,and bearing adjuster. Cover bearing adjuster threads with a light coating of nonhardening sealer. Do not place sealer in the housing threads. Run adjuster up just far enough to hold worm shaft bearings in position.

All parts should be lubricated with recommended lubricant prior to assembly. Handle worm shaft and ball nut to prevent the ball nut from striking the ends of the ball races in the worm. Improper handling could damage ball guides. The deep side of ball nut teeth must face the cover.

Turn the worm shaft from extreme right to extreme left. Do not force against stops. Movement should be smooth with no roughness or binding.

Adjust the worm bearing preload as described earlier in this chapter. See Fig. 33-18.

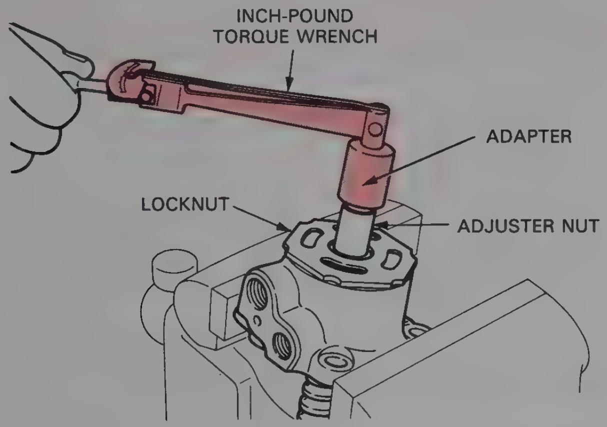


Fig. 33-18. Using an inch-pound torque wrench to adjust worm bearing preload. Securely tighten locknut when finished. (Chrysler)

Install pitman shaft lash adjusting screw. Shim must be in place. Check fit of adjusting screw in pitman shaft. Screw must turn FREELY but with no more than about .002 in. (0.051 mm) end play. If end play is excessive, shims should be used. These are available in several thicknesses. Select one that provides a proper fit, Fig. 33-19.

Lubricate pitman shaft. Insert in housing. To prevent damage to pitman shaft seal (if in position), cover the pitman shaft splines with a single wrap of masking tape.

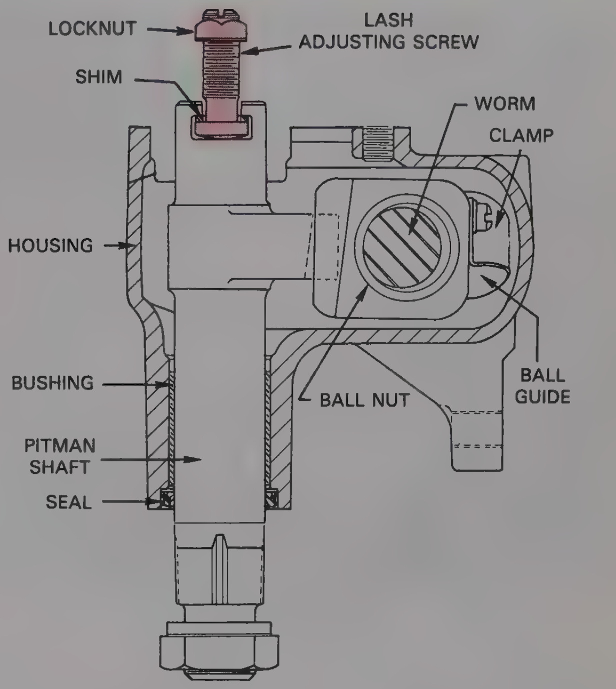


Fig. 33-19. Lash adjuster shim (thrust washer) must allow adjuster to turn freely but with no more than .002 in. or 0.651 mm end play.

Place ball nut in the center of travel and mesh pitman shaft sector teeth, as shown in Fig. 33-9.

Place cover gasket in place, using sealer on both sides. Spread a thin coating of nonhardening sealer on the threads of the cover fasteners and on the threads of the lash adjuster.

Thread the lash adjusting screw through the cover. Lower the cover against the housing by continuing to thread the adjuster screw (counterclockwise) up through the cover.

When the cover is firmly against the housing, insert cover fasteners and bring to correct torque. Never attempt to tighten cover fasteners until the adjuster screw has been threaded through the cover far enough to permit cover to firmly engage housing. Failure to observe this can cause serious damage. Run adjuster locknut into place.

Hold the housing in the normal operating position and fill with approved lubricant.

Adjust pitman shaft sector and ball nut gear teeth depth of mesh. See details on adjustment earlier in this chapter.

When adjustment is complete, check gear for smooth operation. Install gear on car. Torque fasteners. Check gear housing-to-steering shaft alignment. See steering gear housing alignment coverage later in this chapter.

MANUAL STEERING OVERHAUL—RACK AND PINION

When overhaul is necessary, begin by marking the location of the steering shaft coupling on the pinion shaft. Then remove the bolt securing the coupling to the shaft.

Remove outer tie rod ends. Unbolt the rack assembly from the frame cross member. Carefully remove rack assembly from vehicle. Do not catch and tear rubber dust boots. Be sure to secure any shims. See Fig. 33-20.

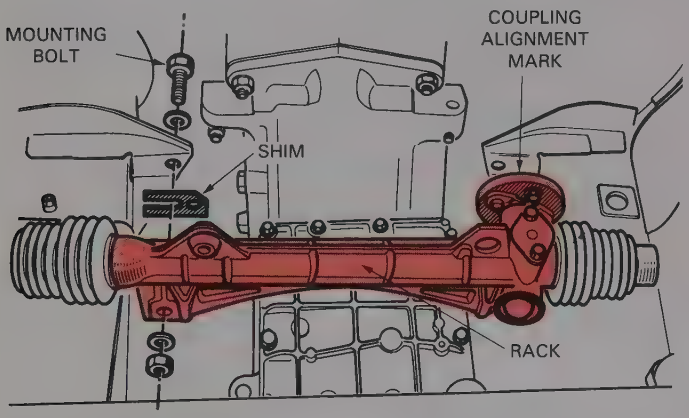


Fig. 33-20. Rack, mounting bolts, and shim location. Other bolt has been removed. Note coupling alignment mark. (Renault)

Mount the rack in a special holding fixture or gently grip with a vise. Obtain a reassembly toe setting by measuring from the center of the tie rod end to the boot retaining groove on both sides. Record these measurements. The measurements will be used during reassembly.

Next, remove outer tie rod ends, dust boots, and clamps. Some units will require new clamps as old ones must be cut off. New boots should always be used.

Remove the inner tie rod ends. Depending upon model, unscrew, drill, or drive out retaining pin. See Fig. 33-21. Remove tie rods.

CAUTION! If the rack has worn or damaged threads, or more than two retaining pin holes in it, a NEW rack or steering gear assembly MUST be installed.

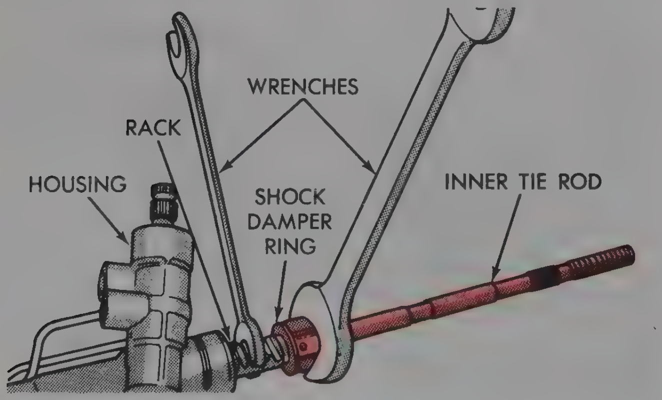


Fig. 33-21. Removing inner tie rod end (screw on type). Note wrench on rack. This prevents undue strain on rack and pinion assembly. (Chrysler)

Remove the steering gear locknut, adjuster plug, spring, and rack bearing (guide). Take off dust cover. Unscrew pinion bearing cap. Remove pinion shaft locknut, snap ring, and withdraw pinion.

Disconnect any remaining fasteners and pull the rack from its housing. Thoroughly clean all metal parts in solvent. Check for wear, cracks, missing teeth, and damaged seals.

An exploded view of a rack and pinion assembly is illustrated in Fig. 33-22.

Reassembly is basically a reversal of disassembly procedures. Follow manufacturer's recommendations for the unit being serviced. Torque all fasteners to specifications and double-check all connections.

POWER STEERING SYSTEMS

Power steering systems utilize oil, under pressure, to provide most of the turning force to the front wheels. These systems assist both front and rear wheels on vehicles equipped with four-wheel steering.

All units use an oil pump, a control valve, and a power cylinder.

POWER STEERING—RACK AND PINION

The power rack and pinion system uses a rotary control valve to regulate the fluid coming from the pump. It routes the fluid to the appropriate side of the rack piston, Fig. 33-23. The piston converts hydraulic pressure to a linear (side to side) movement. This movement is transmitted to the steering arms by the inner and outer tie rods.

CONTROL VALVES

The control valve directs the flow of power steering fluid from one side of the rack piston to the other, Fig. 33-24. As the steering wheel is turned, the resistance created by the vehicle's front tires causes the valve's torsion rod to twist. The twisting action causes a difference in the degree of rotation between the valve and the spool. As this occurs, the passages in the control valve change. Fluid can no longer flow directly through the valve and back into the reservoir. Instead, it must pass through the passages of the power cylinder. For a right turn, a circuit is opened that allows the fluid to be pumped through the spool's top radial groove and into the right side of the power cylinder. At the same time, fluid is discharged from the left side of the power cylinder by the spool's bottom radial groove. This fluid flows back into the valve chamber above the spool and is routed into the reservoir. The opposite circuit is opened for a left turn.

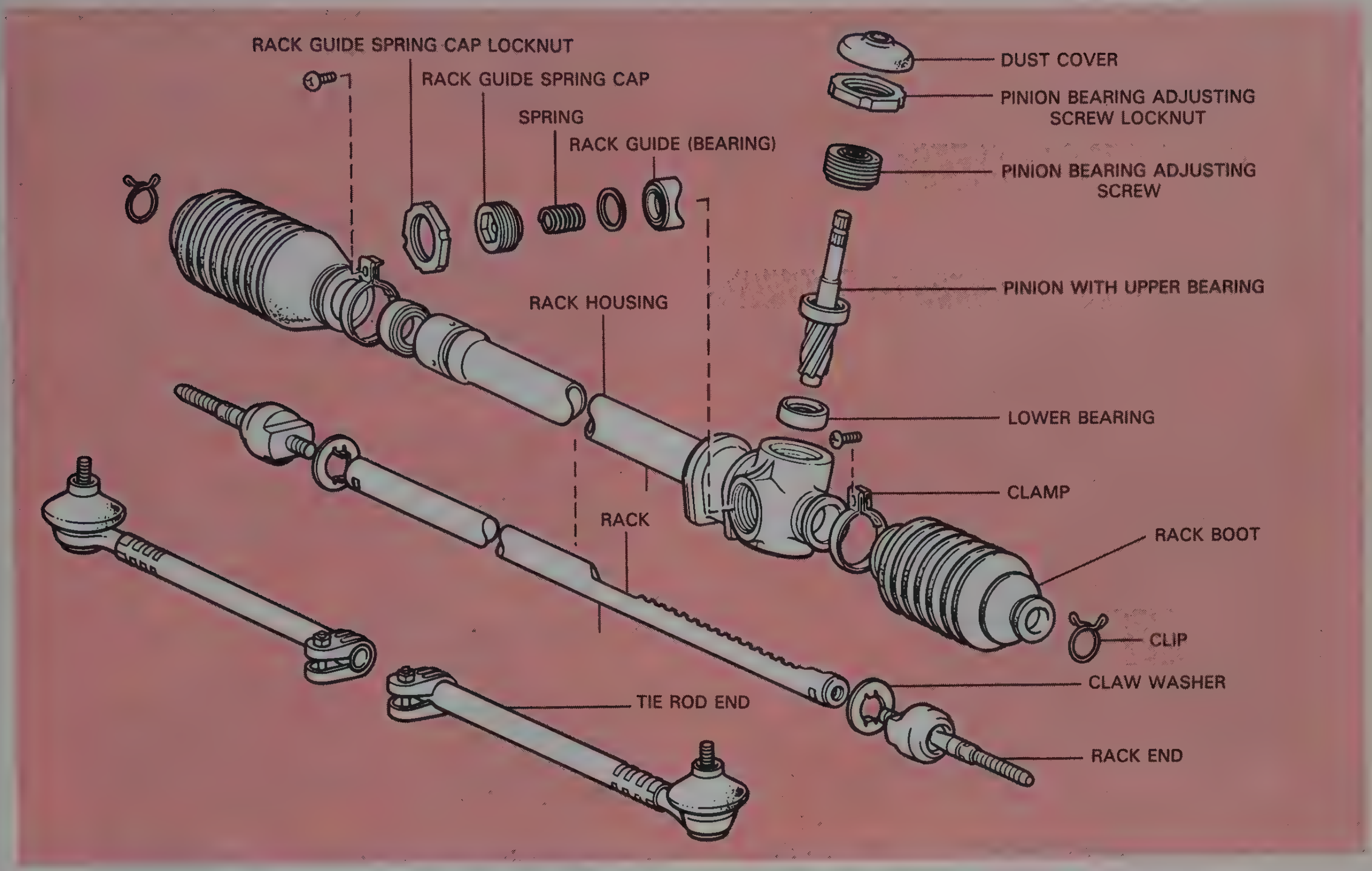

RACK GUIDE SPRING CAP LOCKNUT
RACK GUIDE SPRING CAP
SPRING
RACK GUIDE (BEARING)
DUST COVER
PINION BEARING ADJUSTING SCREW LOCKNUT
PINION BEARING ADJUSTING SCREW
PINION WITH UPPER BEARING
RACK HOUSING
LOWER BEARING
CLAMP
RACK
RACK BOOT
CLIP
CLAW WASHER
TIE ROD END
RACK END

Fig. 33-22. Exploded view of one type of a manual rack and pinion steering assembly. (Toyota)

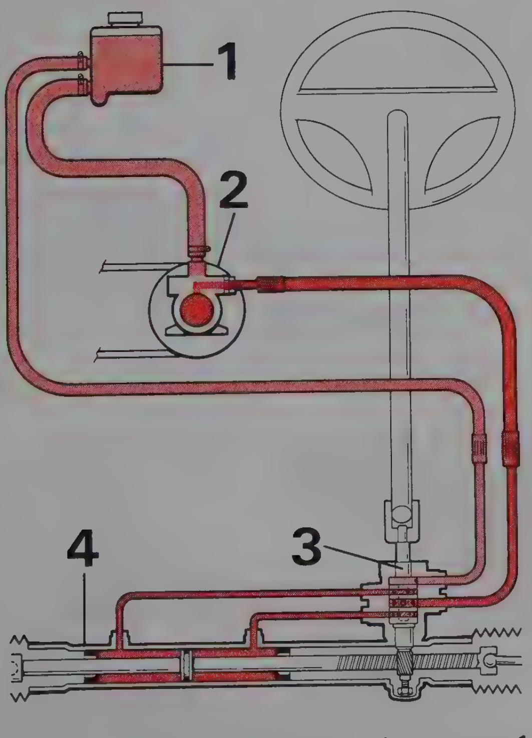


Fig. 33-23. Power rack and pinion steering system. 1—Fluid reservoir. 2—Pump. 3—Torsion rod. 4—Power cylinder. (Saab)

As long as the torsion rod is twisted, hydraulic pressure will act on the rack. The amount of force on the rod will be reduced when the fluid acts on the rack. This reinforces the action of the pinion. The moment the force on the torsion rod is released, the valve's return passage is opened and the fluid will flow directly back into the reservoir.

POWER CYLINDER

The power cylinder is an integral part of the rack housing, Fig. 33-25. There are two power steering fluid lines that run between the cylinder and the control valve. One line is connected on the left side of the piston, and the other line is connected on the right side of the piston. When turning right, fluid is pumped to the right side of the power cylinder, forcing the piston and rack to the left. The fluid is then discharged from the left section of the power cylinder. Simultaneously, the boot on the left side is distended and the boot on the right side is compressed. This causes air to flow through a capillary tube between the boots, keeping the air pressure constant. Movement of the rack is transferred to the steering members by the inner ball joints, tie rods, and tie rod ends.

POWER STEERING—RACK AND PINION OVERHAUL

When an overhaul of the rack and pinion system is necessary, follow all of the manufacturer's recommendations carefully. REMEMBER: Steering is critical. Perform only top-notch work!

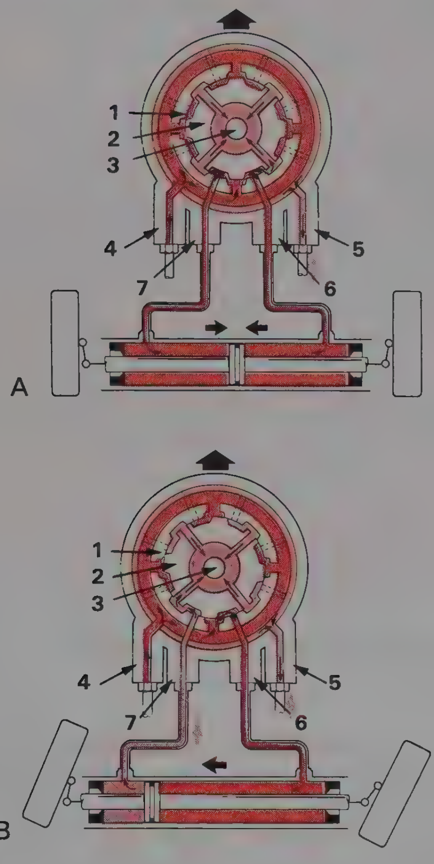


Fig. 33-24. Control valve operation. A—Steering straight ahead. B—Turning right. 1—Spool. 2—Valve. 3—Torsion rod. 4—Pump pressure. 5—Reservoir return. 6—Enter power cylinder during right turn and exit power cylinder during left turn. 7—Enter power cylinder during left turn and exit power cylinder during right turn. (Saab)

POWER STEERING—INTERNAL TYPE

The internal, often called "self-contained," power steering system incorporates a power cylinder geared to the pitman shaft. The power cylinder is an integral part of the steering gear. A control valve is also used in the housing. This is a compact and efficient system and is widely used.

Internal power steering gears are of two general types: offset and in-line.

The offset type power steering gear connects the power piston to the pitman shaft as illustrated in Fig. 33-26.

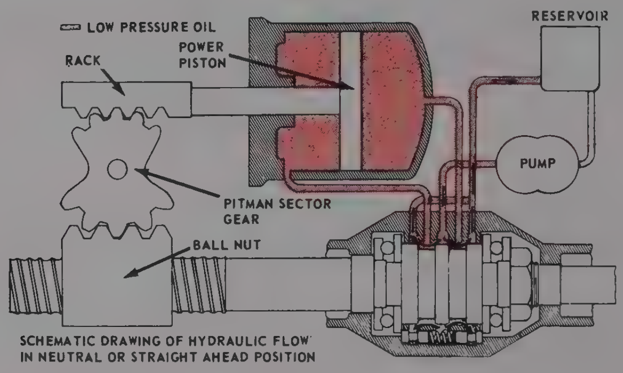

LOW PRESSURE OIL
RESERVOIR
POWER PISTON
RACK
PUMP
PITMAN SECTOR GEAR
BALL NUT
SCHEMATIC DRAWING OF HYDRAULIC FLOW IN NEUTRAL OR STRAIGHT AHEAD POSITION

Fig. 33-26. Offset type of internal power steering gear. (Oldsmobile)

The in-line design (so named because ball nut-power piston, worm shaft, and control valve are all in line) utilizes the recirculating ball nut as a power piston as well. The action of the in-line type, during a turn, is pictured in Fig. 33-27, A. Note how the control valve has admitted oil under pressure (red arrows) to one side of the rack-piston nut. This causes it to move the pitman shaft sector gear. The oil being displaced by the rack-piston nut (white arrows) flows back through the control valve to the pump reservoir.

When the steering wheel is turned hard enough in

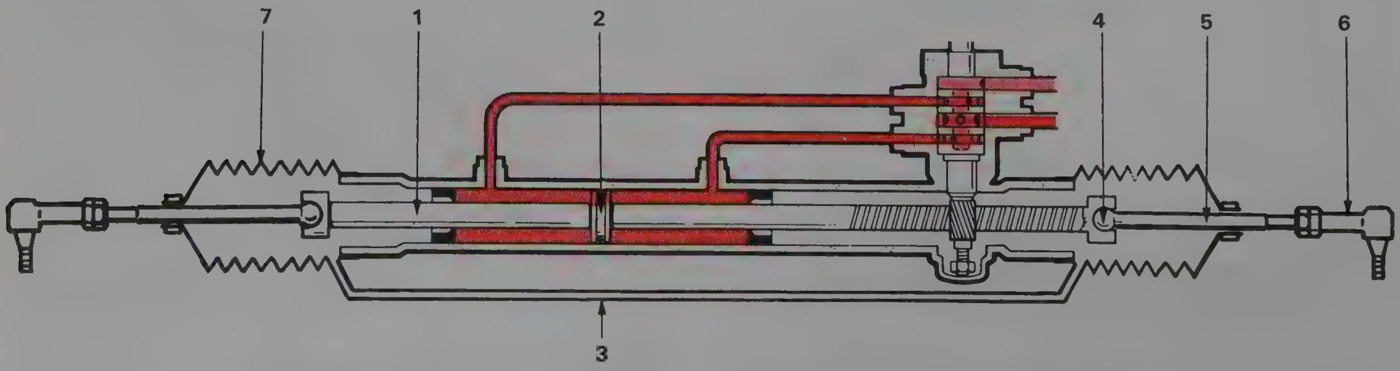


Fig. 33-25. Power cylinder cutaway. 1—Rack. 2—Piston. 3—Pressure equalizing tube. 4—Inner ball joint. 5—Tie rod. 6—Tie rod joint. 7—Boot. (Saab)

the other direction to activate the control valve, oil under pressure (red arrows) is admitted to the opposite side. This forces the rack-piston nut to reverse the direction of the pitman shaft sector gear. See Fig. 33-27, B.

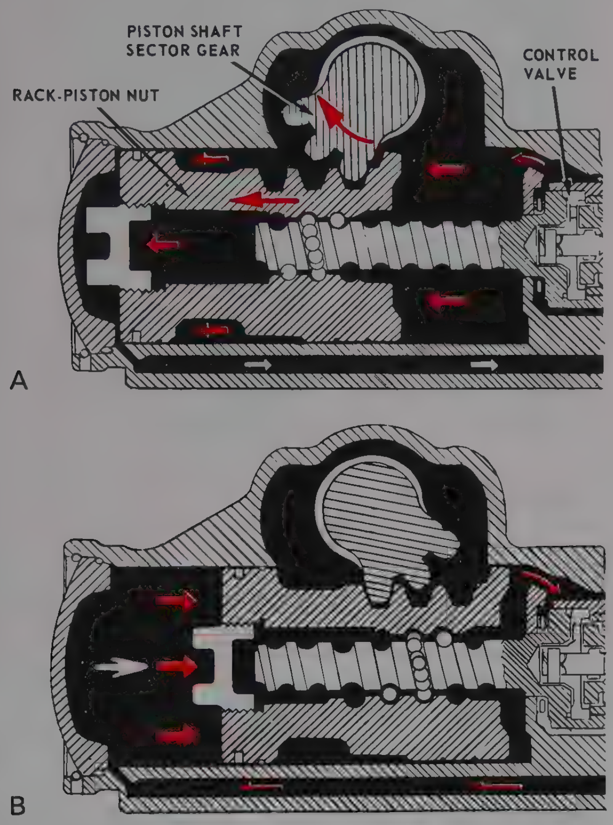


Fig. 33-27. A—Action of in-line type of internal power steering gear during left turn. B—Action of in-line type of power steering gear during a right turn.

The steering gear shown in Fig. 33-28 is typical. It is of the in-line type and utilizes a torsion bar operated spool (rotary) valve. The rack-piston nut utilizes the recirculating ball principle for low friction operation.

Fig. 33-29 illustrates another type of power steering gear.

POWER STEERING GEAR ADJUSTMENTS

The in-line power steering gear has three basic adjustments: thrust bearing preload, worm to rack-piston preload, and pitman shaft over-center preload.

The pitman shaft over-center preload is perhaps the most critical as far as car handling is concerned. This adjustment can usually be made with the steering gear in the car.

CHECKING THRUST BEARING PRELOAD

Thrust bearing preload may be checked with the gear in the car. Adjustment, however, requires removal in some instances.

Remove the pitman arm. If specified, back off pitman shaft lash adjuster. Also, if required, disconnect fluid return line from pump reservoir and drain gear by turning from right to left several times.

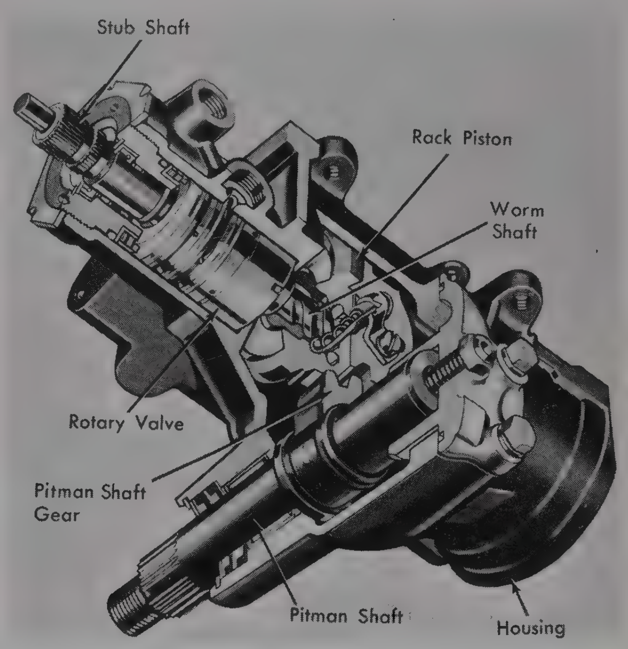


Fig. 33-28. Cutaway view of a typical in-line torsion bar operated spool valve, power steering gear. (Cadillac)

Turn the gear to the extreme right or left and back the specified amount. Using a torque wrench or a spring scale, measure the pull required to move the steering wheel the required distance. This will indicate the thrust bearing preload ONLY, Figs. 33-8 and 33-12.

ADJUSTING THRUST BEARING PRELOAD

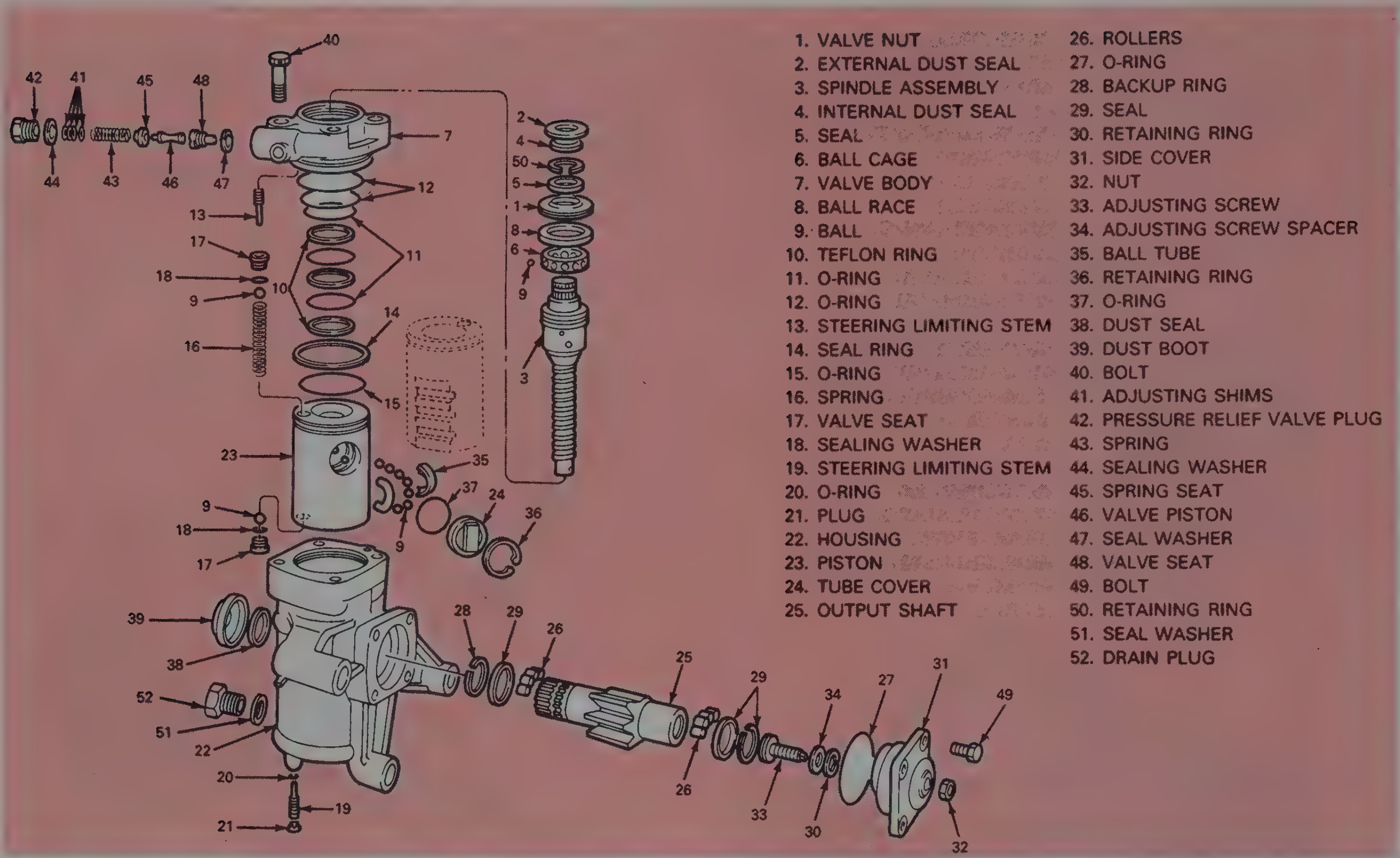
Turn gear stub shaft the specified amount from the center position. Back off pitman shaft lash adjuster screw. Attach an inch-pound torque wrench and turn stud shaft through specified arc.

Tighten or loosen adjuster plug as needed to produce the correct preload. Fig. 33-30 shows how one power steering gear thrust bearing preload is adjusted.

CHECKING WORM TO RACK-PISTON PRELOAD

With the pitman arm removed and the pitman shaft lash adjuster loosened (backed off a couple of turns), move the steering wheel to a position about one-half turn from the center.

Pull the wheel through a very short arc (about 1 in. or 25.4 mm) and note the torque (or scale) reading. The reading should be slightly higher than the thrust



1. VALVE NUT
2. EXTERNAL DUST SEAL
3. SPINDLE ASSEMBLY
4. INTERNAL DUST SEAL
5. SEAL
6. BALL CAGE
7. VALVE BODY
8. BALL RACE
9. BALL
10. TEFLON RING
11. O-RING
12. O-RING
13. STEERING LIMITING STEM
14. SEAL RING
15. O-RING
16. SPRING
17. VALVE SEAT
18. SEALING WASHER
19. STEERING LIMITING STEM
20. O-RING
21. PLUG
22. HOUSING
23. PISTON
24. TUBE COVER
25. OUTPUT SHAFT
26. ROLLERS
27. O-RING
28. BACKUP RING
29. SEAL
30. RETAINING RING
31. SIDE COVER
32. NUT
33. ADJUSTING SCREW
34. ADJUSTING SCREW SPACER
35. BALL TUBE
36. RETAINING RING
37. O-RING
38. DUST SEAL
39. DUST BOOT
40. BOLT
41. ADJUSTING SHIMS
42. PRESSURE RELIEF VALVE PLUG
43. SPRING
44. SEALING WASHER
45. SPRING SEAT
46. VALVE PISTON
47. SEAL WASHER
48. VALVE SEAT
49. BOLT
50. RETAINING RING
51. SEAL WASHER
52. DRAIN PLUG

Fig. 33-29. Exploded view of one type of internal-piston power steering gear unit. (Ford)

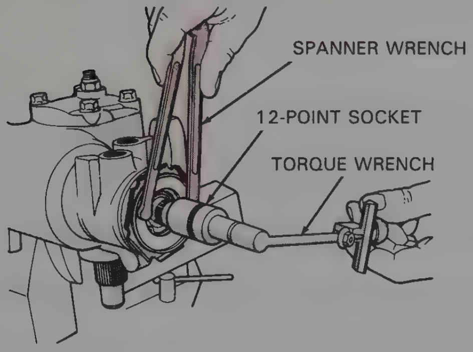


Fig. 33-30. Using a spanner wrench to move adjuster plug until torque wrench indicates correct thrust bearing preload. (Chrysler)

bearing preload reading.

The gear must be dismantled to adjust the worm rack-piston preload.

ADJUSTING WORM TO RACK-PISTON PRELOAD

The worm groove is ground with a high point in the center. When the rack-piston passes this point a mild preload is produced.

Clamp rack-piston (steering gear disassembled) in a vise. Protect rack-piston with jaw covers. Clamp lightly.

With valve assembly in place on the worm, rotate worm until the required distance is obtained from the end of the rack-piston to the thrust bearing face. This locates rack-piston on high point of worm.

With an inch pound torque wrench, rotate the stub shaft in both directions covering an overall arc of about 60 deg. Note torque reading in both directions. Average two highest readings and compare with specifications. Look at Fig. 33-31.

If the preload is lower than required, it may be brought to specifications by replacing the balls with the next larger size.

Service replacement ball sizes, as used by one manufacturer, are shown below. Note the very small size differences.

Size Code	Mean Diameter	Size Range of Ball
6	.28117”	.28112”–.28122”
7	.28125”	.28120”–.28130”
8	.28133”	.28128”–.28138”
9	.28141”	.28136”–.28146”
10	.28149”	.28144”–.28154”
11	.28157”	.28152”–.28162”

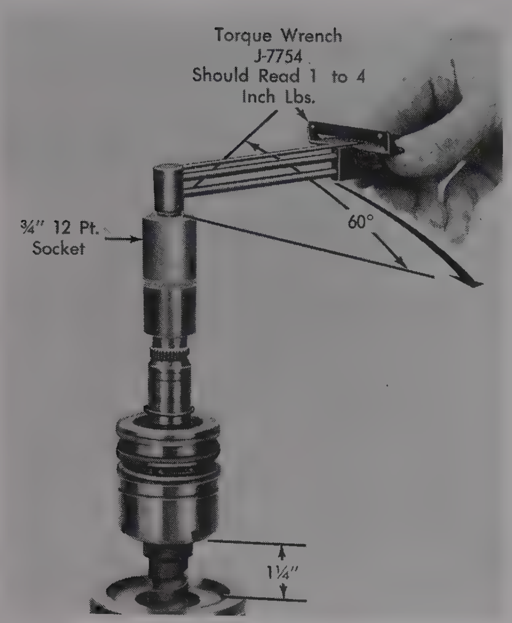


Fig. 33-31. Checking worm to rack-piston preload.

CHECKING PITMAN SHAFT OVER-CENTER PRELOAD

Center steering gear. Using either a torque wrench or spring scale, measure the amount of pull required to move the wheel through the over-center position. Test several times and average the readings.

ADJUSTING PITMAN SHAFT OVER-CENTER PRELOAD

Center steering gear. Move the pitman shaft lash adjuster screw until the torque reading, when the gear is moved over about a 20 deg. arc, is as specified. Tighten adjuster screw locknut.

Fig. 33-32 illustrates how the over-center preload is adjusted on the bench. The procedure is basically the same when on the car. The pitman arm must be disconnected.

POWER STEERING GEAR OVERHAUL

Disconnect pressure and return hoses from steering gear. Elevate hoses. Cap fittings. Plug housing openings.

Remove pitman arm. Mark coupling for correct installation. Remove coupling fastener and steering gear fasteners. Remove gear.

Drain gear. Cycle the rack-piston several times by turning the stub shaft one way then the other. This will assist in complete draining.

Plug hose fitting openings. Clean exterior of gear thoroughly.

Disassemble gear as needed. Clean parts and inspect. Replace parts where required.

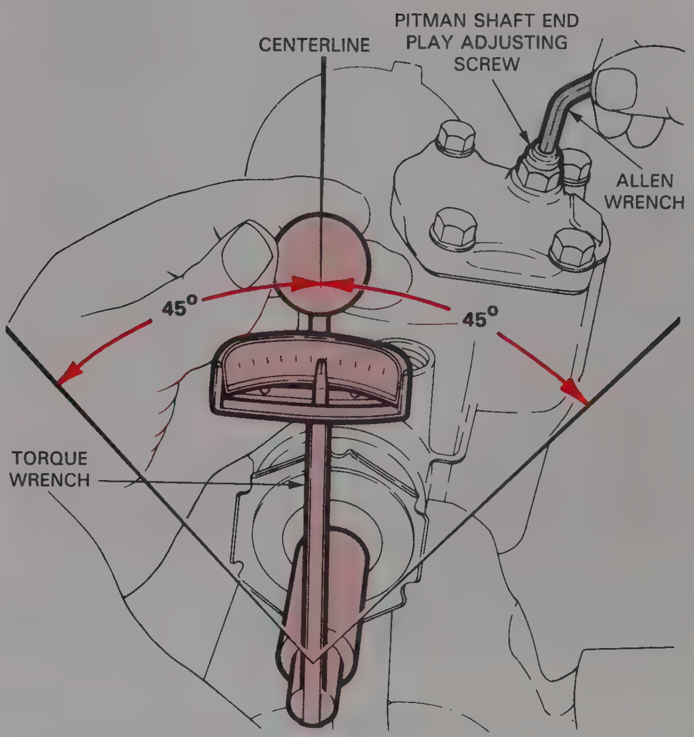


Fig. 33-32. Using a torque wrench and Allen wrench to properly adjust pitman shaft over-center preload. (AMC)

Install new seals, O-rings, gaskets, rack-piston ring, and other parts as needed. Complete rebuilding kits, such as pictured in Fig. 33-33, are available. Assemble in reverse order of disassembly. Make necessary adjustments.

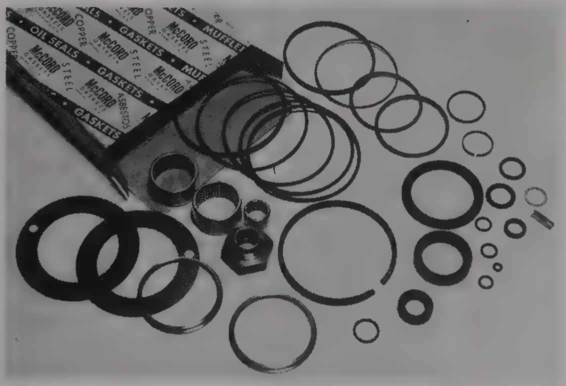


Fig. 33-33. Power steering rebuilding kit. (McCord)

Figs. 33-34 and 33-35 show typical power steering system leakage points.

USE CARE

Clean all parts thoroughly. Handle so as to avoid nicking, burring, or distorting of parts. Keep work

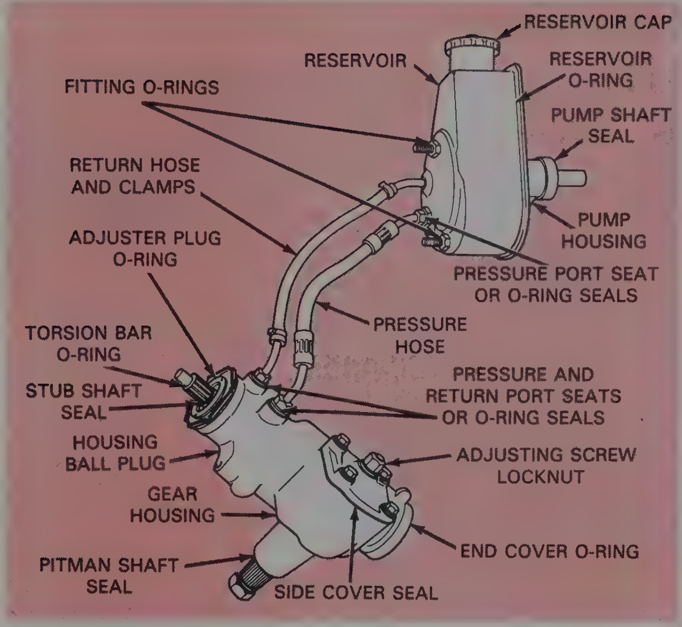

RESERVOIR CAP
RESERVOIR
RESERVOIR O-RING
FITTING O-RINGS
PUMP SHAFT SEAL
RETURN HOSE AND CLAMPS
PUMP HOUSING
ADJUSTER PLUG O-RING
PRESSURE PORT SEAT OR O-RING SEALS
PRESSURE HOSE
TORSION BAR O-RING
PRESSURE AND RETURN PORT SEATS OR O-RING SEALS
STUB SHAFT SEAL
HOUSING BALL PLUG
ADJUSTING SCREW LOCKNUT
GEAR HOUSING
END COVER O-RING
PITMAN SHAFT SEAL
SIDE COVER SEAL

Fig. 33-34. Possible power steering fluid leak points on pump and gear. (AMC)

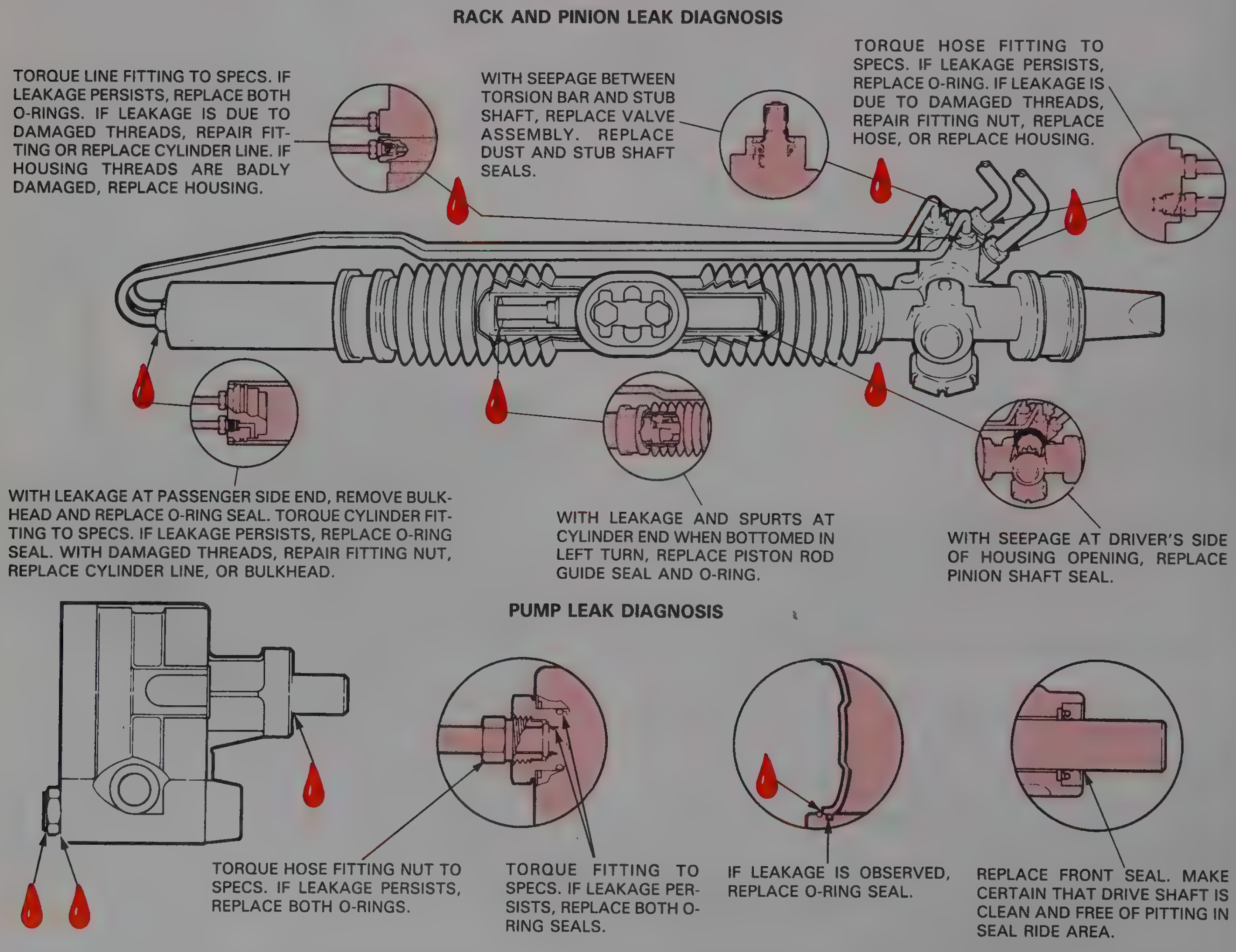
area, tools, and hands clean. Remember that dirt, even in very small amounts, can ruin the power steering gear, pump, control valve, power cylinder, and test instruments. Handle power steering parts carefully. Never strike or hammer the housings. Do not steam clean unless specified by the manufacturer.

STEERING GEAR ALIGNMENT

When reinstalling the steering gear, check for proper alignment with steering shaft. Misalignment can cause bindings and premature wear.

The steering gear, when in the exact center of travel, should be attached to the steering shaft. Make certain steering wheel spokes are in the correct position. All alignment marks should be in line. Fig. 33-36 shows the alignment marks on one setup.

After proper gear housing alignment, the steering wheel should turn through its full travel SMOOTHLY, without roughness or binding.


RACK AND PINION LEAK DIAGNOSIS

TORQUE LINE FITTING TO SPECS. IF LEAKAGE PERSISTS, REPLACE BOTH O-RINGS. IF LEAKAGE IS DUE TO DAMAGED THREADS, REPAIR FITTING OR REPLACE CYLINDER LINE. IF HOUSING THREADS ARE BADLY DAMAGED, REPLACE HOUSING.

WITH SEEPAGE BETWEEN TORSION BAR AND STUB SHAFT, REPLACE VALVE ASSEMBLY. REPLACE DUST AND STUB SHAFT SEALS.

TORQUE HOSE FITTING TO SPECS. IF LEAKAGE PERSISTS, REPLACE O-RING. IF LEAKAGE IS DUE TO DAMAGED THREADS, REPAIR FITTING NUT, REPLACE HOSE, OR REPLACE HOUSING.

WITH LEAKAGE AT PASSENGER SIDE END, REMOVE BULKHEAD AND REPLACE O-RING SEAL. TORQUE CYLINDER FITTING TO SPECS. IF LEAKAGE PERSISTS, REPLACE O-RING SEAL. WITH DAMAGED THREADS, REPAIR FITTING NUT, REPLACE CYLINDER LINE, OR BULKHEAD.

WITH LEAKAGE AND SPURTS AT CYLINDER END WHEN BOTTOMED IN LEFT TURN, REPLACE PISTON ROD GUIDE SEAL AND O-RING.

WITH SEEPAGE AT DRIVER'S SIDE OF HOUSING OPENING, REPLACE PINION SHAFT SEAL.

PUMP LEAK DIAGNOSIS

TORQUE HOSE FITTING NUT TO SPECS. IF LEAKAGE PERSISTS, REPLACE BOTH O-RINGS.

TORQUE FITTING TO SPECS. IF LEAKAGE PERSISTS, REPLACE BOTH O-RING SEALS.

IF LEAKAGE IS OBSERVED, REPLACE O-RING SEAL.

REPLACE FRONT SEAL. MAKE CERTAIN THAT DRIVE SHAFT IS CLEAN AND FREE OF PITTING IN SEAL RIDE AREA.

Fig. 33-35. Rack and pinion and pump leak diagnosis for one particular maker. Note recommended correction with each leak area. (Buick)

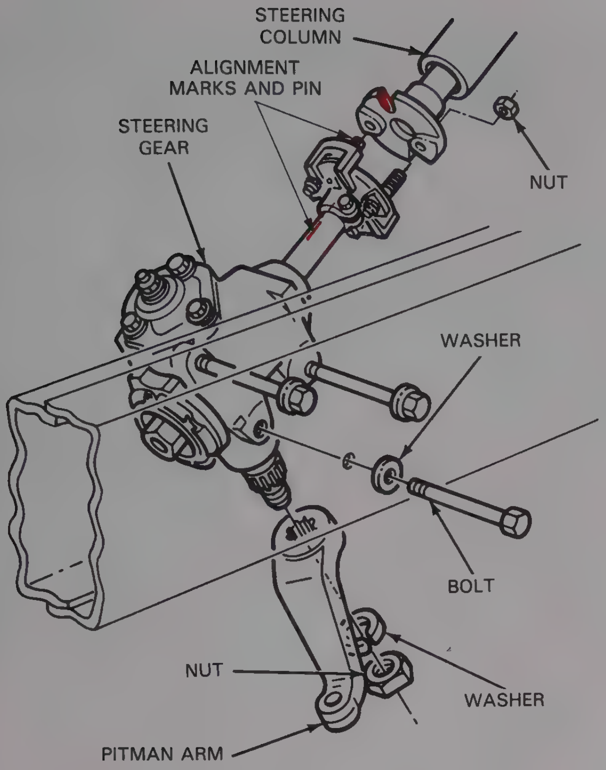


Fig. 33-36. Be sure to align all witness (alignment) marks and pins when reassembling steering gear shaft and coupling. (Ford)

CAUTION! If the vehicle is elevated, do not grasp a front tire and twist it quickly to move the steering wheel to full lock. Severe steering column damage can occur. This is especially true with rack and pinion equipped vehicles.

Gear housing and steering shaft alignment is important. Get it right. Check to make sure gear fasteners and coupling fasteners are torqued to specifications.

Attach and torque pitman arm. Connect to linkage.

STEERING COLUMN PROBLEMS

Squeaks, roughness, binding, etc., can be caused by worn, dirty, or dry steering shaft (in steering column) bearings. Column looseness or misalignment also can cause trouble.

Fig. 33-37 shows one manufacturer's various steering column assembly arrangements. An exploded view of a tilt steering column assembly is pictured in Fig. 33-38.

ADJUSTING STEERING WHEEL SPOKE POSITIONING

If the steering wheel is mounted on the steering shaft so that marks are in alignment, the spoke position, if incorrect, must be altered by moving the tie-rod ad-

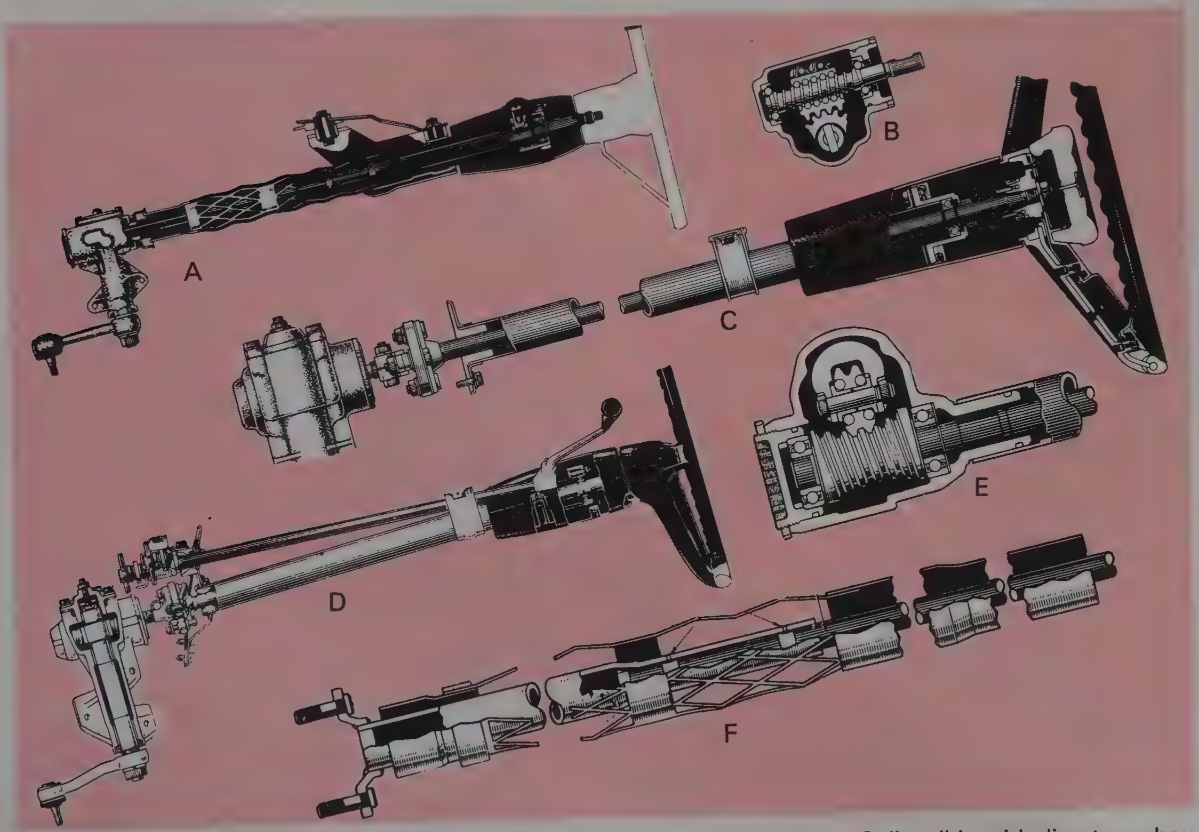


Fig. 33-37. Several steering column assembly variations by one maker. A—Collapsible with direct gearbox arrangement. B—Cross section of recirculating ball gearbox. C—Column with flexible drive to gearbox. D—Column with external shift tube. E—Cross section of a worm and roller gearbox. F—Details of collapsible column and telescoping steering shaft. (Toyota)

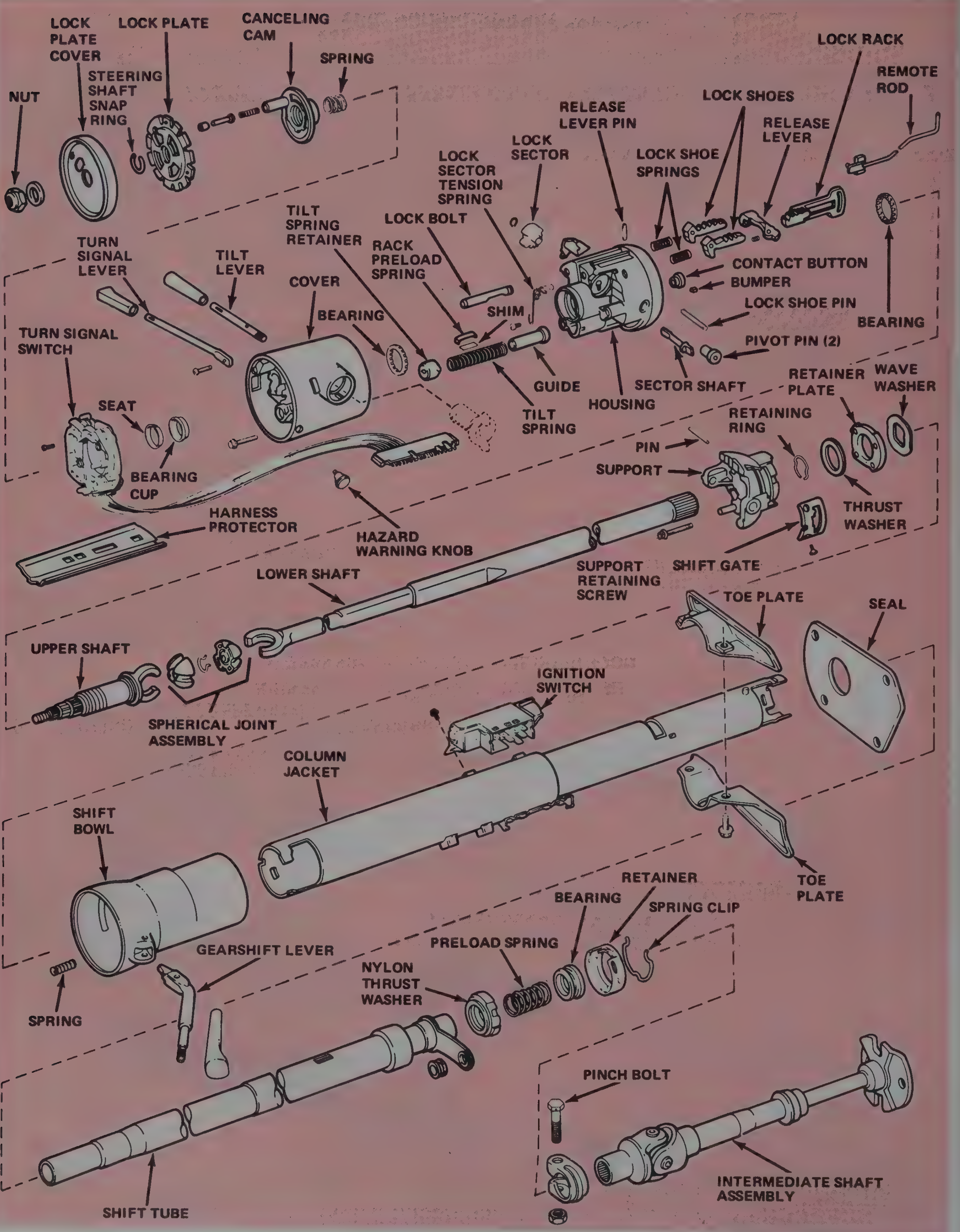

LOCK PLATE COVER
LOCK PLATE
CANCELING CAM
SPRING
STEERING SHAFT SNAP RING
NUT
LOCK RACK
REMOTE ROD
LOCK SHOES
RELEASE LEVER PIN
RELEASE LEVER
LOCK SECTOR
LOCK SHOE SPRINGS
LOCK SECTOR TENSION SPRING
LOCK BOLT
TILT SPRING RETAINER
RACK PRELOAD SPRING
TURN SIGNAL LEVER
TILT LEVER
COVER
CONTACT BUTTON
BUMPER
LOCK SHOE PIN
BEARING
SHIM
BEARING
TURN SIGNAL SWITCH
PIVOT PIN (2)
GUIDE
SECTOR SHAFT
RETAINER PLATE
WAVE WASHER
HOUSING
TILT SPRING
SEAT
RETAINING RING
PIN
SUPPORT
BEARING CUP
THRUST WASHER
HARNESS PROTECTOR
HAZARD WARNING KNOB
SUPPORT RETAINING SCREW
SHIFT GATE
LOWER SHAFT
TOE PLATE
SEAL
UPPER SHAFT
IGNITION SWITCH
SPHERICAL JOINT ASSEMBLY
COLUMN JACKET
SHIFT BOWL
TOE PLATE
RETAINER
BEARING
SPRING CLIP
PRELOAD SPRING
GEARSHIFT LEVER
NYLON THRUST WASHER
SPRING
PINCH BOLT
INTERMEDIATE SHAFT ASSEMBLY
SHIFT TUBE

Fig. 33-38. Exploded view of a tilt steering column. Note spherical joint assembly which allows wheel to be moved up and down. Study parts and learn their names. (Jeep)

juster sleeves. For complete details on this operation, see adjusting toe-in and steering wheel position (center point steering) in Chapter 32—Wheels, Bearings, Tires.

STEERING WHEEL REMOVAL

Remove the wheel center ornamental cap and other parts required to expose the steer wheel retaining nut. Remove nut. Check wheel and shaft for alignment marks. If none are used and if the wheel is to be replaced in the SAME position, mark wheel and shaft. Use a suitable puller to remove the wheel. Refer to Fig. 33-39.

Some setups are fitted with a safety retaining ring that snaps into a groove above the nut. Remove carefully.

NEVER hammer on the end of the steering shaft. Damage to the column and/or collapsible joint can occur. Use CAUTION when working with systems equipped with air bags!

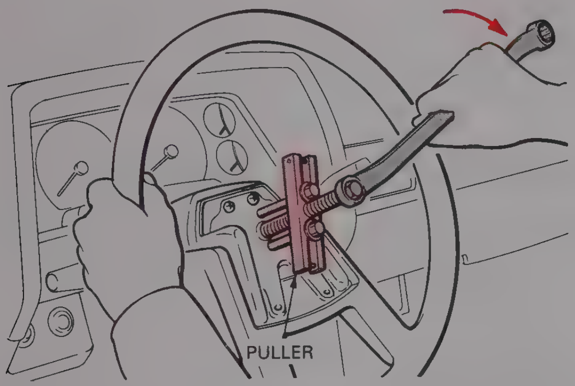


Fig. 33-39. Using a puller to remove steering wheel. Be careful not to damage steering shaft threads. (Chrysler)

STEERING WHEEL INSTALLATION

Install the parts that precede the steering wheel, in reverse order in which they were removed. Install the wheel on the steering shaft, aligning the marks to insure proper positioning of the spokes of the wheel. See Fig. 33-40.

If no aligning marks are used, center the steering gear and mount the wheel with the spokes in proper position for straight ahead driving.

Install the washer and wheel retaining nut. Torque the retaining nut to specified tightness. Stake the nut to lock it in place, or coat exposed threads with locking compound.

POWER STEERING PUMPS

Power steering pumps, Figs. 33-41 to 33-46, usually are VANE, SLIPPER, or ROLLER types. All use a cam ring with cam-shaped inner opening. A rotor turns inside the cam ring. The rotor may employ vanes to form a seal between the rotor and cam. Fig. 33-42 pictures a typical vane type power steering pump.

Note how the vanes contact the pump ring cam-shaped inside. When the rotor turns, each space formed between the rotor and ring by the vanes, will grow from a small size, Fig. 33-43, to a large size. This will form a vacuum and fill the space between the vanes with oil.

As the rotor continues to turn, the space will reduce in size, Fig. 33-43. This will compress the oil and force it through the outlet of the power steering pump.

The vanes are kept in contact with the ring cam walls by centrifugal force and by oil pressure fed to the base of each vane.

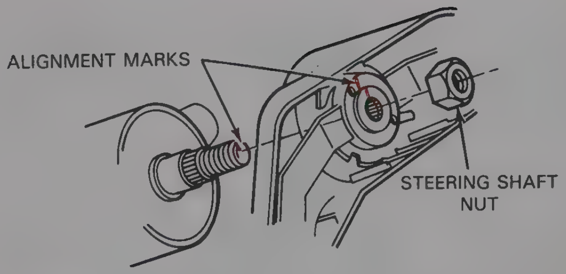


Fig. 33-40. When replacing steering wheel be sure alignment marks line up. (Ford)

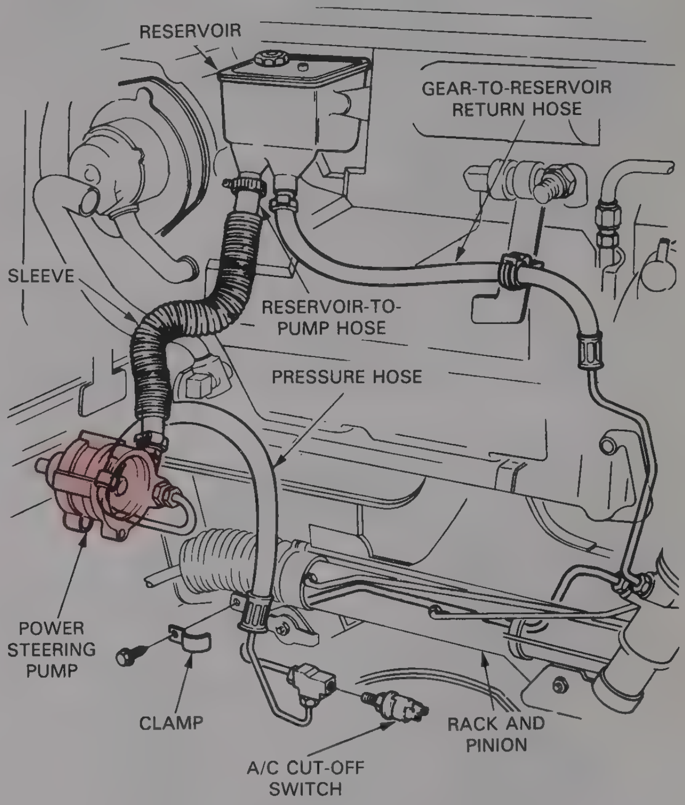


Fig. 33-41. Power rack and pinion steering system. This pump uses a remote fluid reservoir. (GM)

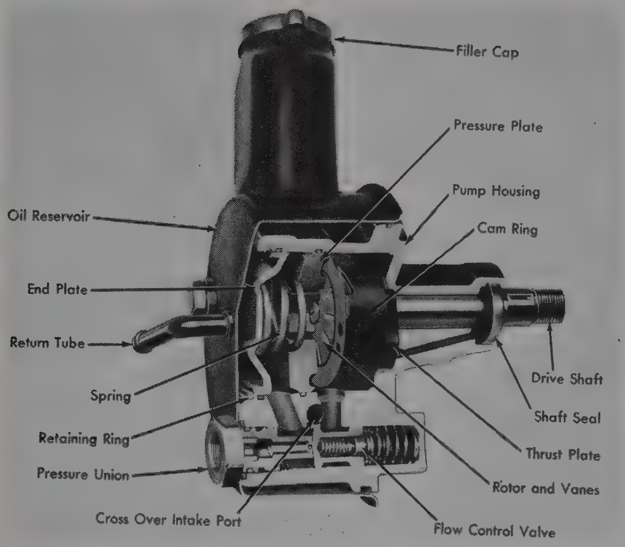

Filler Cap
Pressure Plate
Pump Housing
Oil Reservoir
Cam Ring
End Plate
Return Tube
Drive Shaft
Spring
Shaft Seal
Retaining Ring
Thrust Plate
Pressure Union
Rotor and Vanes
Cross Over Intake Port
Flow Control Valve

Fig. 33-42. Typical vane-type power steering pump.

The pump design in Fig. 33-43 has a pumping action on both sides. This gives it a balanced pumping action.

The pump in Fig. 33-44 uses spring-loaded slippers to form a seal between rotor and ring. This is a slipper-type pump. Note oil flow through pump.

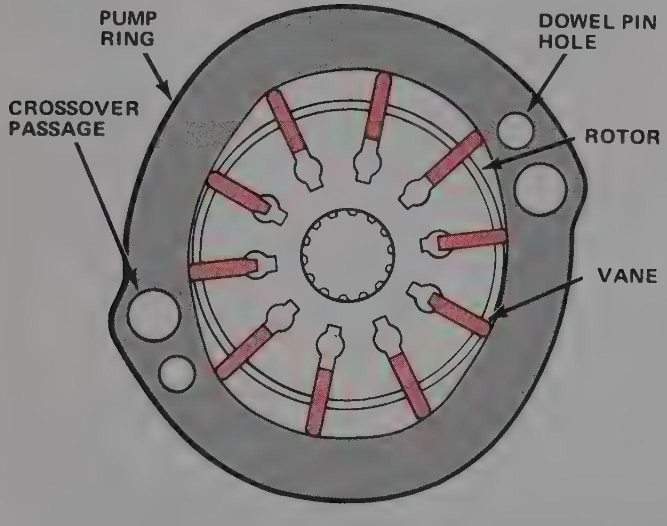

PUMP RING
DOWEL PIN HOLE
CROSSOVER PASSAGE
ROTOR
VANE

Fig. 33-43. Vane type power steering pump. Note relationship of rotor and vanes to pump ring. (AMC)

The roller pump utilizes a series of rollers in preference to vanes or slippers, Fig. 33-45.

A gear-type power steering pump is illustrated in Fig. 33-46.

METHODS OF DRIVING POWER STEERING PUMP

Most installations utilize one or two V-belts to drive the power steering pump. The belt or belts operate from the engine crankshaft pulley. See Fig. 33-47.

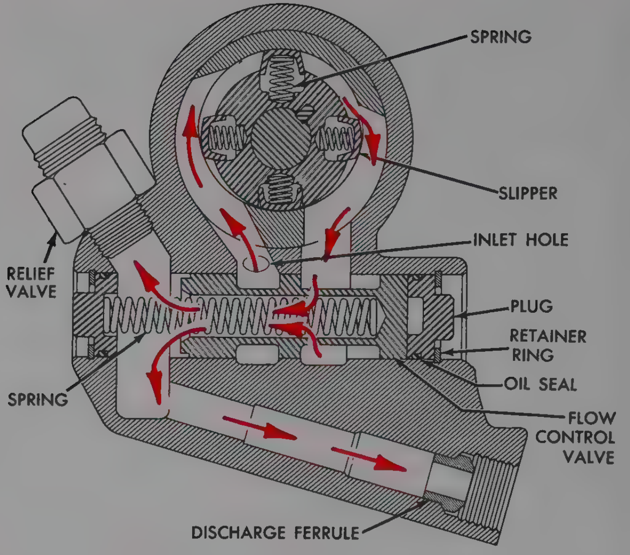

SPRING
SLIPPER
INLET HOLE
RELIEF VALVE
PLUG
RETAINER RING
OIL SEAL
SPRING
FLOW CONTROL VALVE
DISCHARGE FERRULE

Fig. 33-44. Slipper type steering pump. (Dodge)

Fig. 33-41 illustrates a typical power steering arrangement that employs a single belt drive. Note that the fluid reservoir is separate from the pump on this setup.

POWER STEERING PUMP OVERHAUL

Leaking seals, worn or damaged parts, or scoring require pump disassembly and repair.

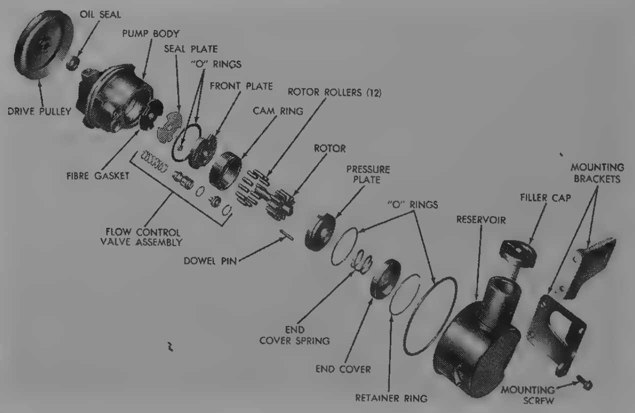

OIL SEAL
PUMP BODY
SEAL PLATE
"O" RINGS
FRONT PLATE
ROTOR ROLLERS (12)
DRIVE PULLEY
CAM RING
ROTOR
FIBRE GASKET
PRESSURE PLATE
MOUNTING BRACKETS
FILLER CAP
"O" RINGS
RESERVOIR
FLOW CONTROL VALVE ASSEMBLY
DOWEL PIN
END COVER SPRING
END COVER
RETAINER RING
MOUNTING SCREW

Fig. 33-45. Exploded view of a roller type power steering pump. Note location of rotor rollers. (Chrysler)

When removing the pump pulley, use a PULLER. NEVER TRY TO HAMMER THE PULLEY OFF. Look at Fig. 33-48.

Some pumps have Fiberglas/nylon reservoirs which can be damaged by prying or hammering.

Clean pump exterior before disassembly. Oil should be drained.

Disassemble pump as required. Use care to avoid ex-

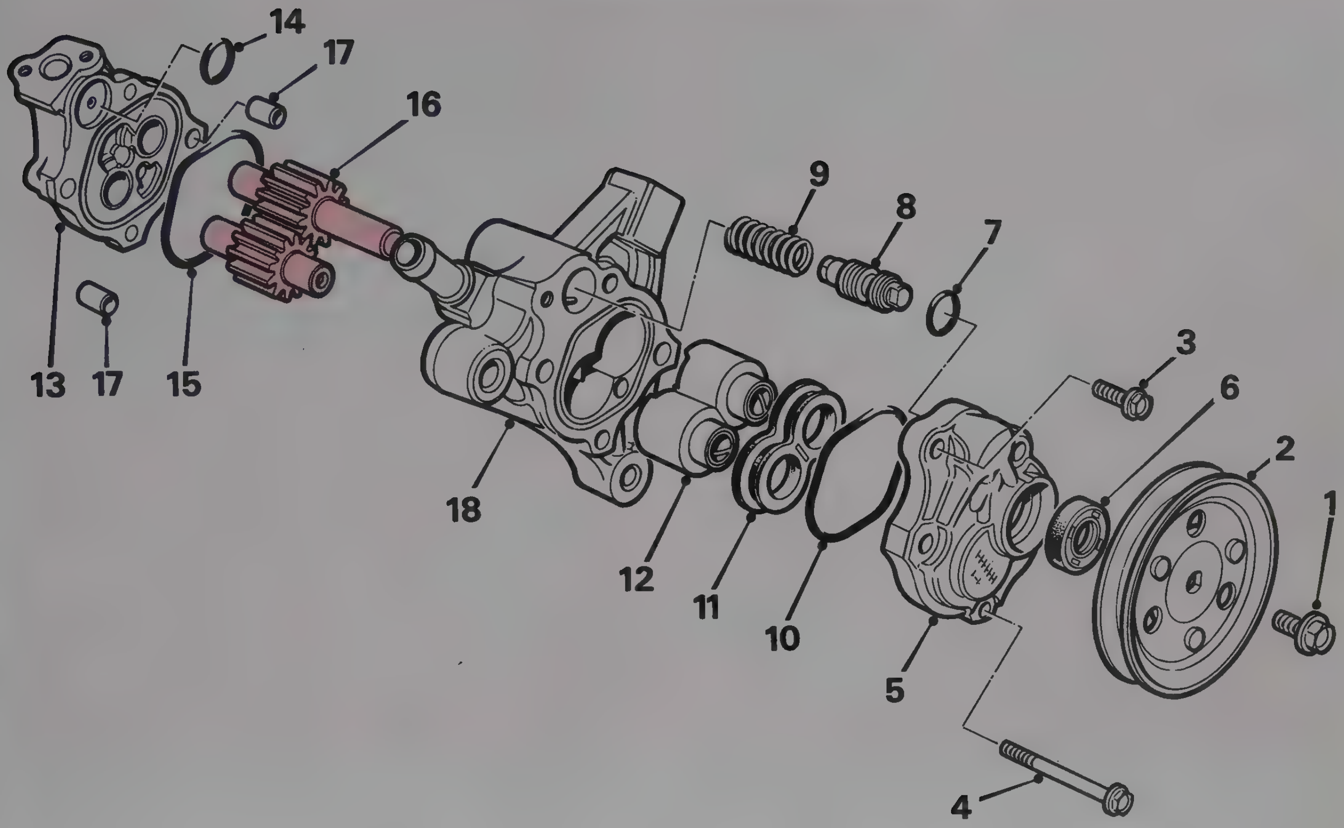


Fig. 33-46. Exploded view of a gear-type power steering pump assembly. 1—Pulley bolt. 2—Pulley. 3—Cover bolt. 4—Cover bolt. 5—Cover. 6—Shaft seal. 7—O-ring. 8—Control valve. 9—Control valve spring. 10—Sealing ring. 11—Plunger seal. 12—Plungers. 13—Rear cover. 14—O-ring. 15—Sealing ring. 16—Gears. 17—Dowels. 18—Gear housing. (Sterling)

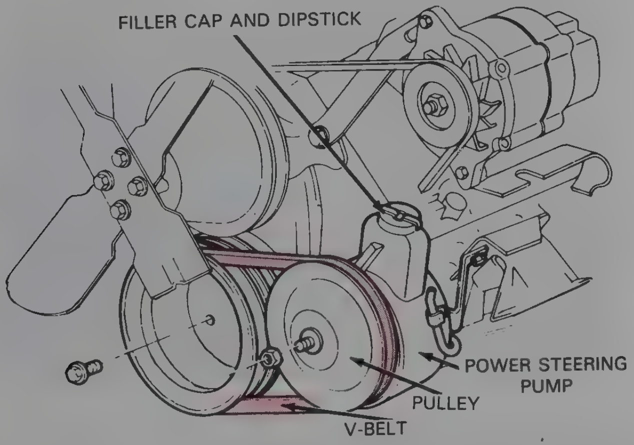


Fig. 33-47. Most power steering pumps are belt driven. (Chevrolet)

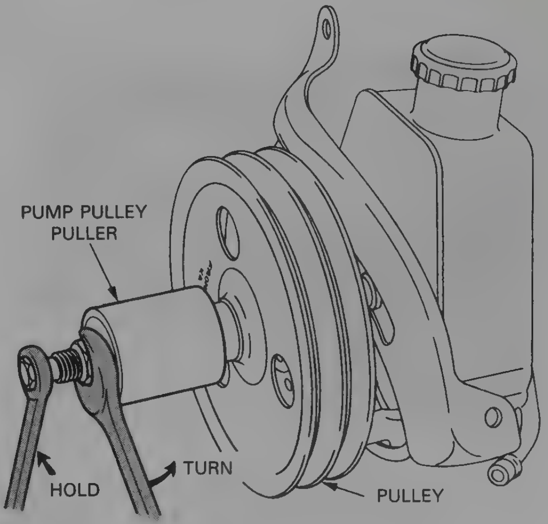


Fig. 33-48. Removing pulley from power steering pump with a special puller. (Chevrolet)

cessive force. Clean all parts and lay out on a CLEAN table. Fig. 33-49 shows a typical vane-type pump completely disassembled.

Carefully inspect all parts for excessive wear. Check for galling, nicks, or other physical damage. Check flow control valve. Replace damaged or worn parts.

When assembling, lubricate all parts with appropriate fluid. Some setups, such as when power steering fluid is used to operate the power brake booster (Hydro-Boost), require special fluid. Always use the exact fluid specified by the manufacturer. Install parts in the correct direction. Vane rounded ends must ride against cam ring.

To facilitate proper installation of parts without damage to the O-rings, use a coating of petrolatum.

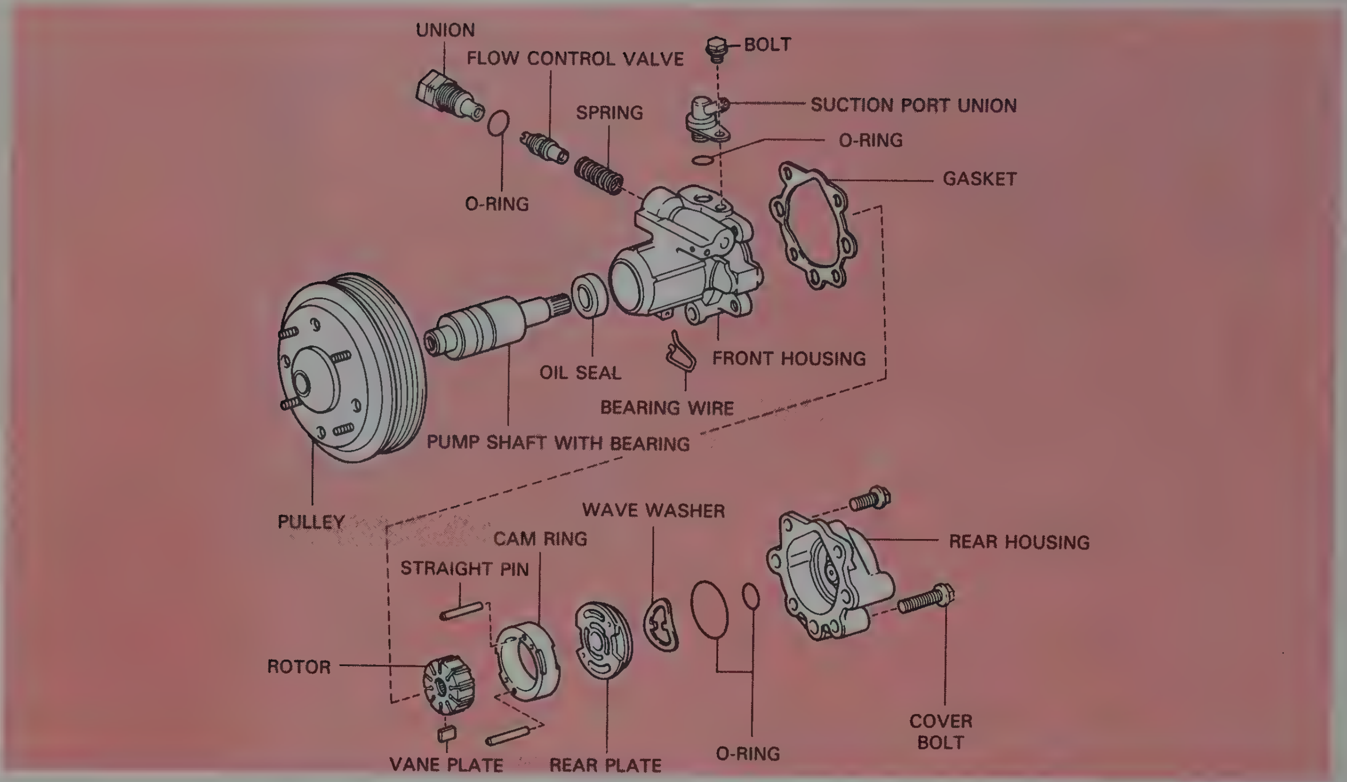

UNION
FLOW CONTROL VALVE
BOLT
SUCTION PORT UNION
SPRING
O-RING
GASKET
O-RING
FRONT HOUSING
OIL SEAL
BEARING WIRE
PUMP SHAFT WITH BEARING
PULLEY
WAVE WASHER
CAM RING
REAR HOUSING
STRAIGHT PIN
ROTOR
COVER BOLT
O-RING
VANE PLATE
REAR PLATE

Fig. 33-49. Exploded view of a vane-type power steering pump. (Toyota)

Install NEW seals, O-rings, and gaskets. Protect seal when inserting rotor drive shaft. Fig. 33-50 illustrates the use of a shaft seal protector.

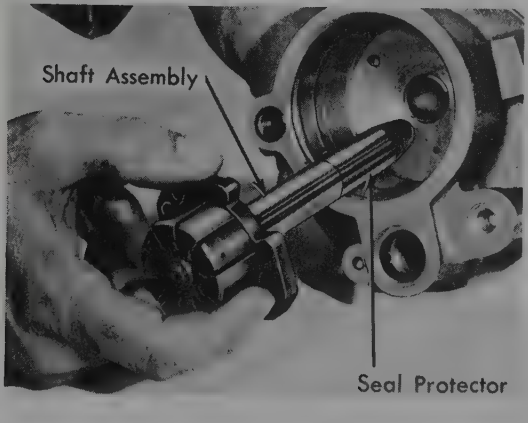

Shaft Assembly
Seal Protector

Fig. 33-50. By using a seal protector, shaft can be passed through seal without damage.

If the pressure plate is spring-loaded, as in Fig. 33-42, use a press to depress the end plate while inserting the retaining (snap) ring. See Fig. 33-51.

Make certain the flow control valve springs are not distorted, nicked, or damaged. Install springs and valve correctly.

Install pulley and mount on engine. Adjust belt tension. Make certain pulley drive key is in place. See adjusting power steering pump drive belts later in this chapter.

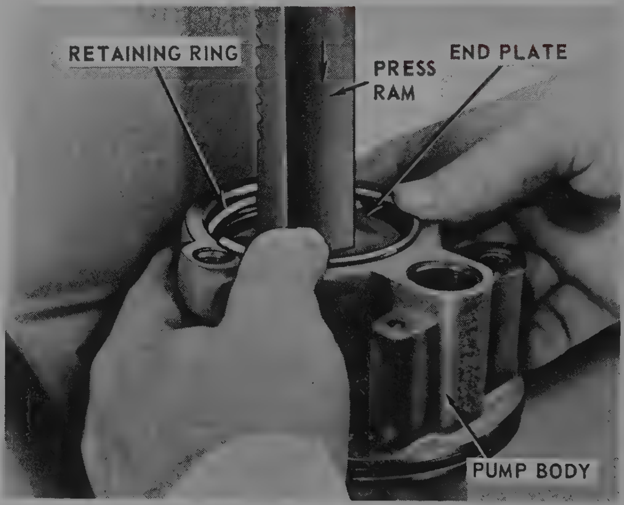

RETAINING RING
PRESS RAM
END PLATE
PUMP BODY

Fig. 33-51. Using a press to facilitate pump end plate retaining ring installation.

SEAL REPLACEMENT

If a leaking drive shaft seal is the only trouble, it can often be replaced "on-the-car."

The first step in on-the-car seal replacement is to remove the pulley. Next, pry out old seal. Then drive in a new seal using a suitable driving tool, Fig. 33-52.

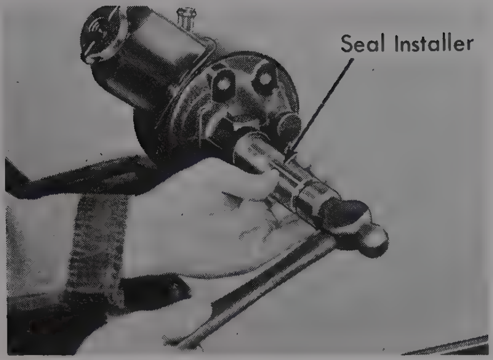


Fig. 33-52. Installing a pump drive shaft seal without disassembling pump.

POWER STEERING HOSE REPLACEMENT

Remove hose or hoses from the steering pump. Cap pump outlets. Tip hose down into a container to drain. Remove from power steering gear or from linkage power piston control valve.

Install new hose. Tighten fittings to specifications. Use quality replacement hose. Install HIGH PRESSURE hose on the pump outlet-to-gear circuit.

STEERING SYSTEM SWITCHES

Some manufacturers incorporate a pressure sensing switch into the power steering pump. This switch protects the engine from overloading by controlling idle speed. It can also cycle the air conditioning compressor on and off.

INSPECT STEERING LINKAGE

Raise the car and inspect all steering linkage connections. Check ball sockets for looseness by shaking the center link and tie rods. Check idler arm mounting fasteners. Check pitman arm retaining nut tension.

Inspect tie rod sleeve adjusters and sleeve clamp bolts. Check steering arm fasteners. All cotter pins should be in place.

Tighten loose fasteners and replace worn joints and leaking grease seals. Check for bent parts. See section on linkage tie rod end replacement later in this chapter.

If a linkage power steering setup is used, check power piston and control valve for physical damage or leaking. Repair or replace as needed.

CHECK STEERING GEAR

Check lubricant level in steering gear (manual type). Check gear alignment. Turn gear from full left to full right and back to detect any roughness or bind.

Shake steering wheel as much as possible WITHOUT MOVING FRONT WHEELS (ENGINE OFF) to check for gear wear or maladjustment. If needed, adjust worm shaft thrust preload and pitman shaft overcenter preload. Inspect flexible coupling between gear housing and steering shaft.

INSPECT POWER STEERING PUMP BELTS

Carefully inspect power steering belts for glazing, rotting, cracking, or swelling. Replace as needed.

If excessive belt squeal occurs during sharp turning of the front wheels, the belt is probably loose and should be adjusted. Adjustment may be checked by using a belt tension gauge. Replace or adjust belt as needed. See power steering belt adjustment and replacement later in this chapter.

INSPECT POWER STEERING PUMP AND LUBRICANT LEVEL

Check fluid level in power steering pump. Fluid should be between add and full marks. Check with fluid at operating temperature. The pump illustrated in A, Fig. 33-53, has a dipstick to make checking easy. The pump in B requires removal of the cover to check level.

Clean top before removal to prevent dirt entry into reservoir. When replacing the cover in type B, do not overtighten the center bolt. The covers are, in some cases, easily cracked.

If fluid level is down, inspect entire system for leaks. See Figs. 33-34 and 33-35.

INSPECT POWER STEERING HOSE

Carefully inspect each power steering hose. Check for softness, swelling, cracking, abrasion, etc. Replace where needed.

Inspect hose fittings for cracking and looseness. Torque fittings.

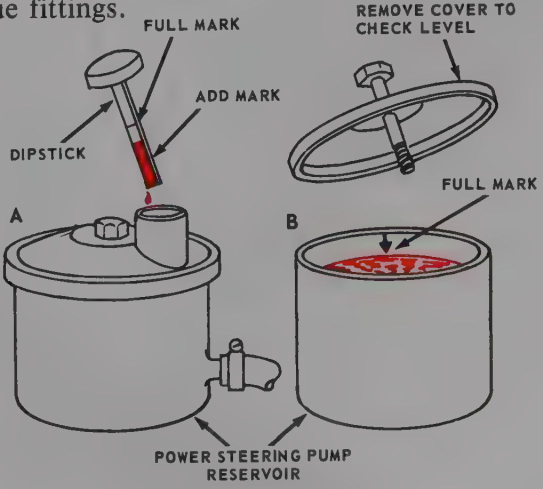


Fig. 33-53. Keep power steering pump filled to proper level. A—Use dipstick to check level. B—Remove cover to determine level.

INSPECT POWER STEERING PUMP COOLER

If the car is equipped with a power steering pump cooler, check it for leakage. Clean cooler surface. See Fig. 33-54.

POWER STEERING SYSTEM PRESSURE TEST

By conducting a system pressure test, pressure problems can be easily identified as to origin. Problems may be found in the pump itself or in the hose or gear system.

There are three major factors involved in a pressure test: proper test connections, correct engine rpm, and specified fluid temperature.

Before conducting a pressure test, belt tension must be checked. If needed, adjust the belts. Fluid level must be as specified.

Remove the high pressure outlet hose from the pump. Insert a 0-2000 psi (0-13 790 kPa) gauge and shutoff valve between the disconnected hose and the pump outlet. The gauge must be between the shutoff valve and the pump, Fig. 33-55.

Torque fittings. OPEN GAUGE FULLY.

If the manufacturer's specifications call for an EXACT rpm and fluid temperature, install a thermometer in the pump reservoir and connect a tachometer, Fig. 33-56.

Bleed the system by starting the engine and turning the steering wheel from full right to left and back several times. Check fluid level and add if needed.

Run engine until fluid temperature reaches indicated level. Shutoff must be open. Run engine at specified rpm and note pressure with valve open (wheels in straight ahead position).

Turn the steering wheel (weight of car on wheels) to the right or left until the stop is reached. Hold the wheel hard against the stop and read the maximum pressure developed. Never hold the wheels hard against the stops for longer than five seconds. This will cause a rapid rise in fluid temperature and damage the pump.

Check pressure against specifications. Pressure specifications generally call for somewhat over 1,000 psi (6 895 kPa).

If the pressure is below an acceptable level, SLOWLY CLOSE THE SHUTOFF VALVE (wheels in straight ahead position). If the pressure rises to the proper level with the valve OFF, the pump is all right and the pressure drop is in the hoses or gear system. If pressure does not rise, the pump is at fault.

Never leave the shutoff valve in the closed position longer than five seconds. To do so would cause a rapid fluid temperature rise with possible pump damage.

Some manufacturers' specifications call for checking maximum pressure by using the shutoff valve only (not holding wheel against stop).

BLEEDING STEERING SYSTEM

When a hydraulic steering system has been repaired, an accurate fluid level reading cannot be obtained unless trapped air is bled from the system. A basic bleeding procedure is as follows:

1. Shut the engine off. Lift the vehicle's front wheels off the ground and turn them all the way to the

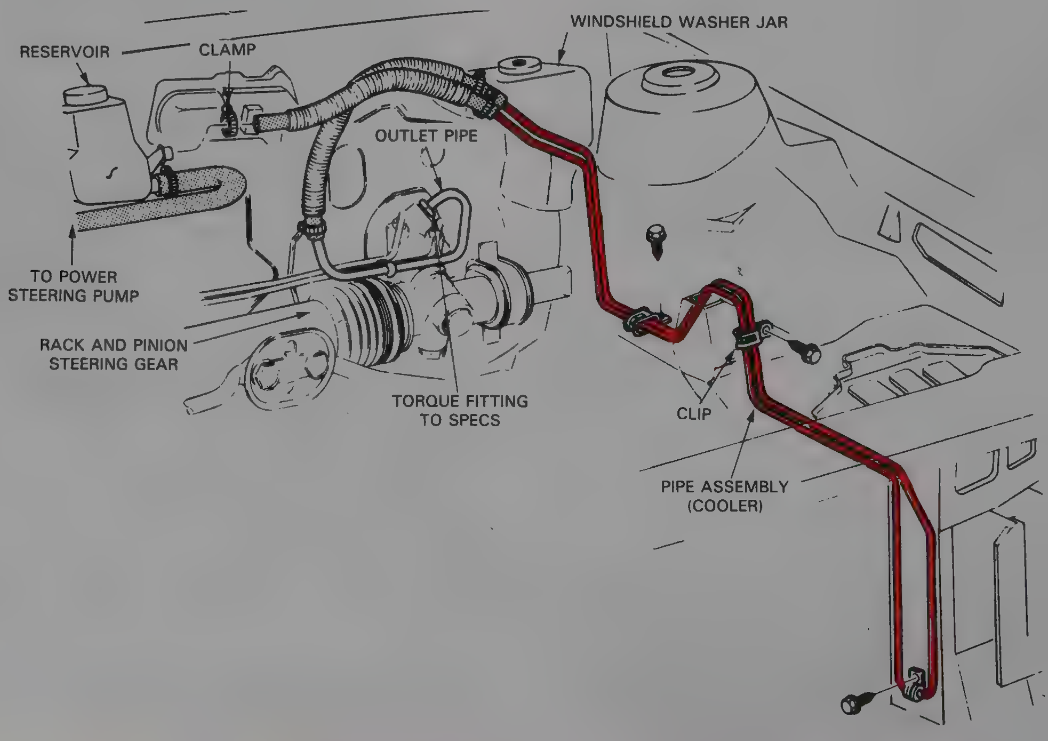


Fig. 33-54. One type of power steering pump cooler. Check cooler pipe for kinks, cracks, or loose hose connections. Air passing over length of pipe (tubing) reduces temperature of fluid. (Chevrolet)

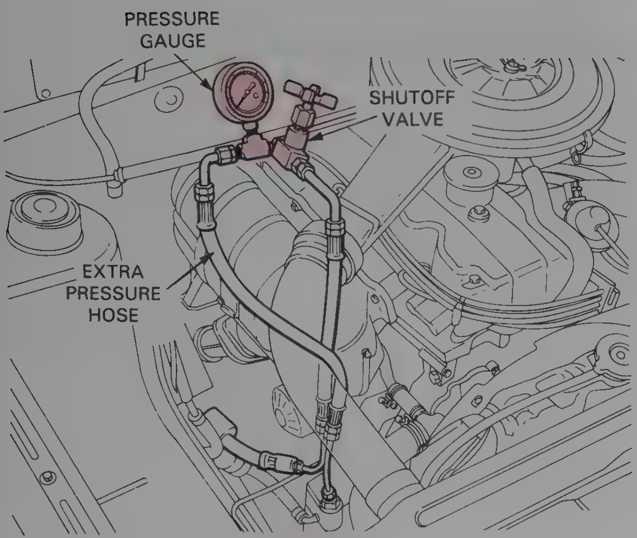


Fig. 33-55. Setup used for obtaining power steering pressure. Follow maker's directions carefully. Wear goggles! (Chrysler)

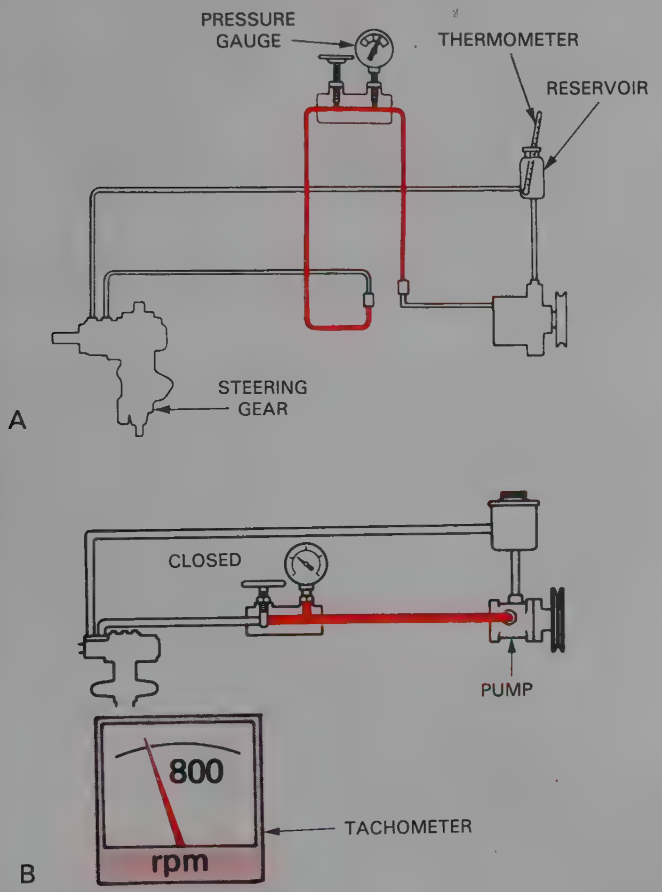


Fig. 33-56. A—Some pressure tests call for the use of a thermometer and gauge. B—Tachometer and pressure gauge may also be needed. Do not keep gauge shutoff closed for more than about five seconds. (Chrysler & Toyota)

left. Fill reservoir to "full cold" line.

2. Bleed the system by turning the wheels from side to side (do not contact steering stops). Keep the fluid at the "full cold" mark. Fluid mixed with air may have a tan color.
3. Start the engine and let it idle. Check the fluid level and add if necessary.
4. Center the wheels and lower the car to the floor. Allow the engine to run for 2 or 3 minutes and check for leaks.
5. Road test the vehicle. Check for abnormal steering function, noise, and leaks.
6. Check the fluid level (now at the "full hot" mark) and add if necessary. Do not overfill!

POWER STEERING BELT ADJUSTMENT AND REPLACEMENT

If a vehicle does not use a serpentine belt with an automatic self-adjuster, belt tension may be checked in three ways: torque wrench, tension gauge, and by belt deflection.

The torque wrench method calls for adjusting belt tension until a certain torque is required to turn the power steering pump pulley.

The belt deflection method requires pressing inward on a certain spot and measuring the resultant amount of belt deflection.

The strand tension gauge is the most accurate method of testing belt tension. The instrument is slipped around the belt and the pump moved in or out until the tension gauge reads as specified.

Be careful when prying on pumps to adjust belt tension. Pry only on the heavy section. If the pump is equipped with a special wrench tab, use it. Never pry on the reservoir or filler neck.

If the belt needs adjustment, loosen pump attaching fasteners. Pry pump outward as needed. Tighten

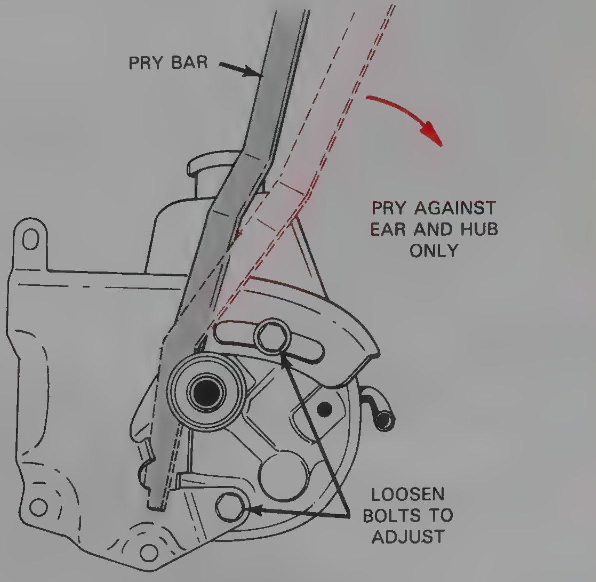


Fig. 33-57. Using a pry bar, carefully force pump outward to loosen belts for removal. Follow manufacturer's recommendations! (Oldsmobile)

fasteners, Fig. 33-57.

To replace the belt or belts, loosen fasteners. Rotate pump inward to slack belts. Remove belts. Install new belts and tension as specified. See Fig. 33-58.

New belts are tensioned somewhat tighter than used belts to compensate for initial stretching and seating.

When removing and installing belts, disconnect the battery ground strap to prevent injury.

See the chapter on belts and hoses for additional details.

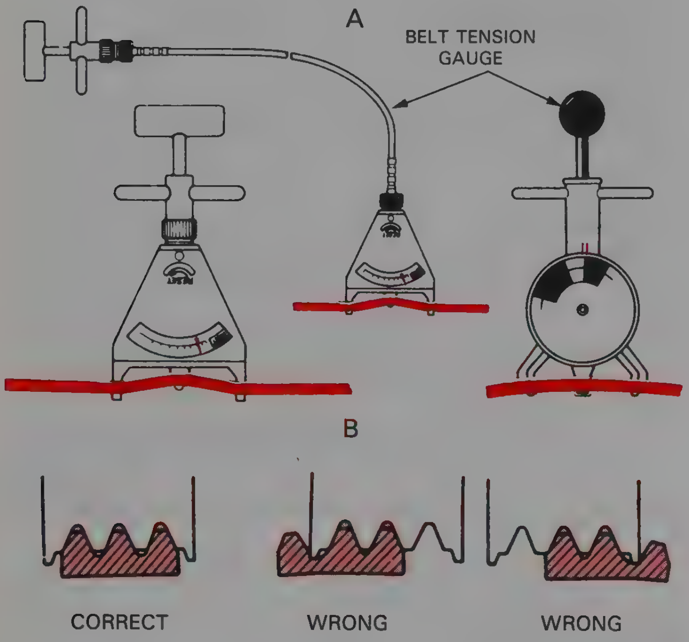

A
BELT TENSION GAUGE
B
CORRECT
WRONG
WRONG

Fig. 33-58. A—Tension gauges are used to check for proper belt tension. B—Belt should always be installed on the pulley correctly. (Toyota)

STEERING LINKAGE

Steering linkage arrangements vary depending upon need and basic design. One typical arrangement is illustrated in Fig. 33-59.

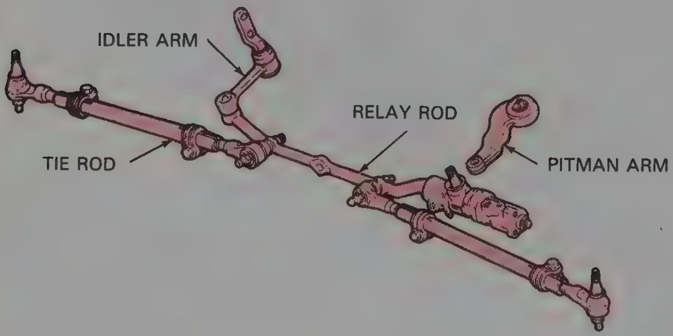

IDLER ARM
RELAY ROD
TIE ROD
PITMAN ARM

Fig. 33-59. A parallelogram steering linkage arrangement. (Chevrolet)

REMOVING AND INSTALLING PITMAN ARM

Remove pitman arm-to-pitman shaft retaining nut. Install a suitable puller. Tighten puller until pitman arm pulls free. Protect pitman shaft and threads. Do not hammer on the end of the puller or on the end of the pitman shaft. Hammering could damage the steering gear. See Fig. 33-60.

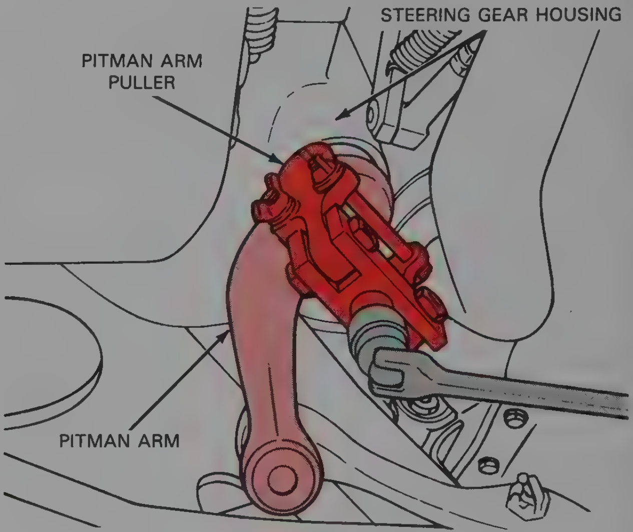

STEERING GEAR HOUSING
PITMAN ARM PULLER
PITMAN ARM

Fig. 33-60. Using a special puller to remove pitman arm from steering gear. (Ford)

To remove the pitman arm from the drag link or from the center link ball socket stud, see section on linkage ball socket removal.

To install the pitman arm, clean the end of the pitman shaft THOROUGHLY. Lubricate pitman shaft splined area.

Install pitman arm on shaft. Be certain to align arm and shaft correctly, Fig. 33-61.

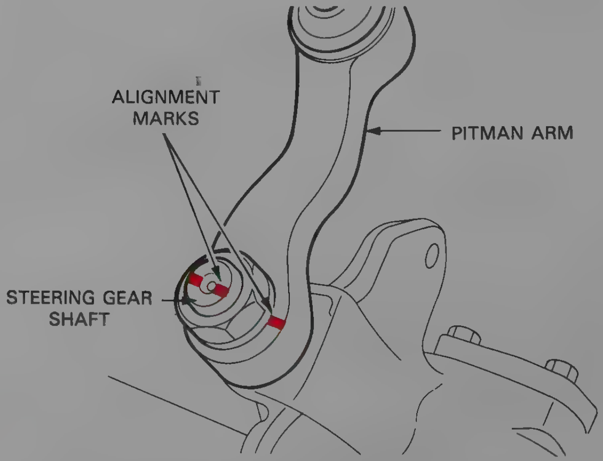

ALIGNMENT MARKS
PITMAN ARM
STEERING GEAR SHAFT

Fig. 33-61. Alignment marks on pitman arm and steering gear shaft. (Plymouth)

Install lock washer and retaining nut. Torque nut to specifications. Support one side of the pitman arm (section on shaft). With a heavy hammer, rap the other side with a sharp blow. Never hammer on the retaining nut or against the end of the shaft. Torque the nut again. The sharp blow will assist in proper seating of the pitman arm on the shaft. Stake the nut to prevent loosening.

TIE ROD END (BALL SOCKET) CONSTRUCTION AND REMOVAL

Fig. 33-62 illustrates typical tie rod ball socket construction. In A, note the half-ball type, while B employs the full ball design. Note that a plug is used to allow periodic lubrication.

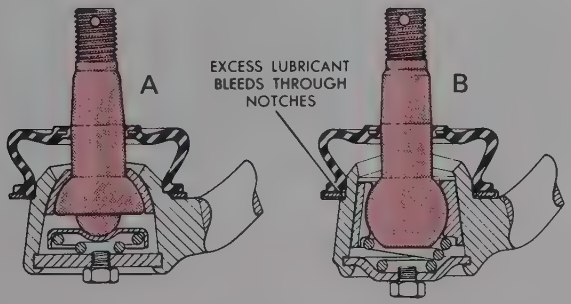


Fig. 33-62. Tie rod end (ball socket) construction. (Chrysler)

Remove cotter pin and retaining nut.

If the tie rod end is found to be worn out by checking deflection (looseness), it should be discarded. See Fig. 33-63. A power removing tool or puller, such as shown in Fig. 33-64, may be used. This power tool will ruin the seal.

A puller, as pictured in Fig. 33-65, will remove the tie rod end without damage to the seal or to the socket.

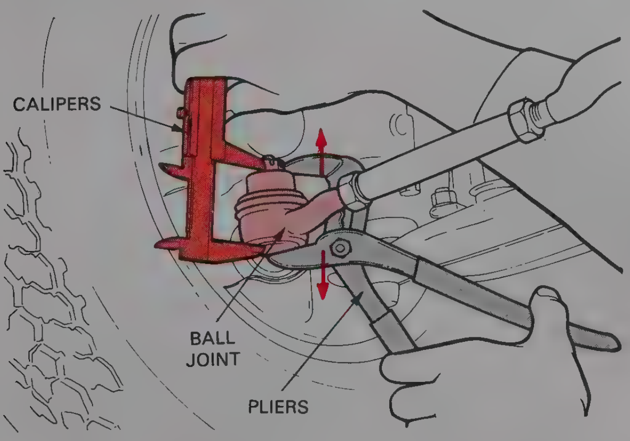


Fig. 33-63. Grip ball joint with pliers. Compress fully. Measure. Service limit (allowable wear) for this joint is .060 in. (1.5 mm). (Chrysler)

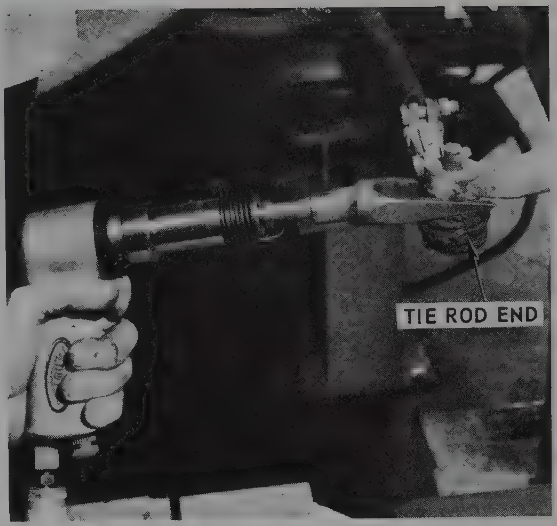


Fig. 33-64. Removing tie rod end with power tool. (Albertson)

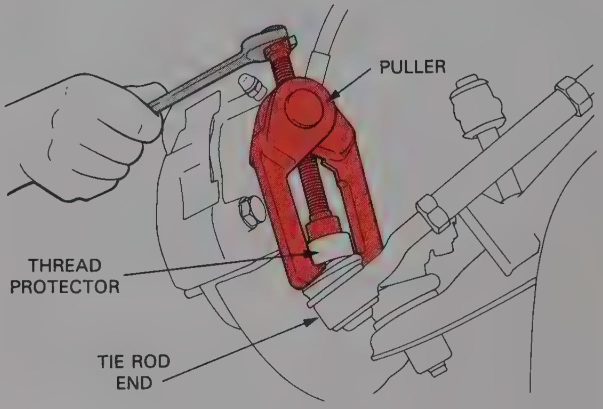


Fig. 33-65. Removing a tie rod end with puller. Note thread protector. (Plymouth)

Note use of a thread protector.

If a puller is not available, the tie rod stud can be removed by hammering on one side of the steering arm while supporting the other with a heavy block of steel.

When installing the tie rod ball stud, clean the stud and the tapered hole into which it fits. Wipe stud with a thin coat of oil.

Insert stud and run retaining nut up. Torque to specifications. While supporting the steering arm with a block of steel, rap the arm sharply several times with a hammer. Retorque. Insert cotter pin and bend ends open.

TIE ROD ADJUSTER SLEEVE INSTALLATION

Clean the adjuster thoroughly, inside and out. Clean tie rod and tie rod end threads. Lubricate adjuster sleeve threads.

Force tie rod and tie rod end against adjuster sleeve while sleeve is turned. Continue turning sleeve until toe-in is correct.

The tie rod and tie rod end should have about the same number of threads turned into the adjusting sleeve.

Position the adjuster sleeve clamps so they are over the threaded portion of the tie rod and tie rod end in the sleeve. The sleeve slot and clamp opening should be correctly aligned.

Torque clamp bolts to specifications.

Fig. 33-66 illustrates a typical linkage system. Note tie rod end construction, clamp arrangement, and other parts.

IDLER ARM REPAIR

Some installations require replacing the idler arm when the arm becomes loose. Other setups allow new bushings or bearings to be inserted. When looseness is evident, remove the old bushing and insert a new one from a replacement kit.

Fig. 33-67 illustrates the use of a special puller to remove one type of worn bushing. The same tool may be used to draw the replacement bushing into position.

Controlled friction and ball bearing repair kits are available for certain cars.

Torque all idler arm fasteners. Install cotter pins. Check for binding. Lubricate if required.

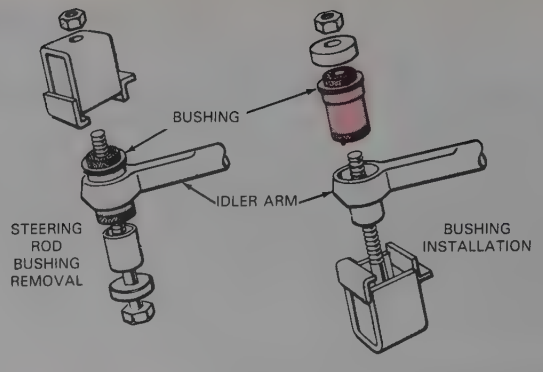

BUSHING
IDLER ARM
STEERING ROD BUSHING REMOVAL
BUSHING INSTALLATION

Fig. 33-67. Removing idler arm looseness by installing new bushing.

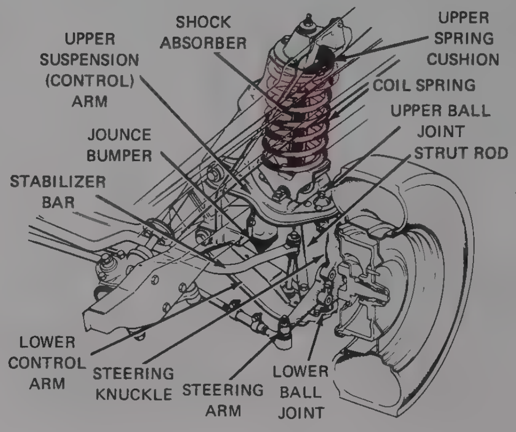

UPPER SUSPENSION (CONTROL) ARM
SHOCK ABSORBER
UPPER SPRING CUSHION
COIL SPRING
UPPER BALL JOINT
STRUT ROD
JOUNCE BUMPER
STABILIZER BAR
LOWER CONTROL ARM
STEERING KNUCKLE
STEERING ARM
LOWER BALL JOINT

Fig. 33-68. One form of coil spring front suspension system. Note coil is located between UPPER suspension (control) arm and body. (American Motors)

FRONT SUSPENSION SYSTEMS

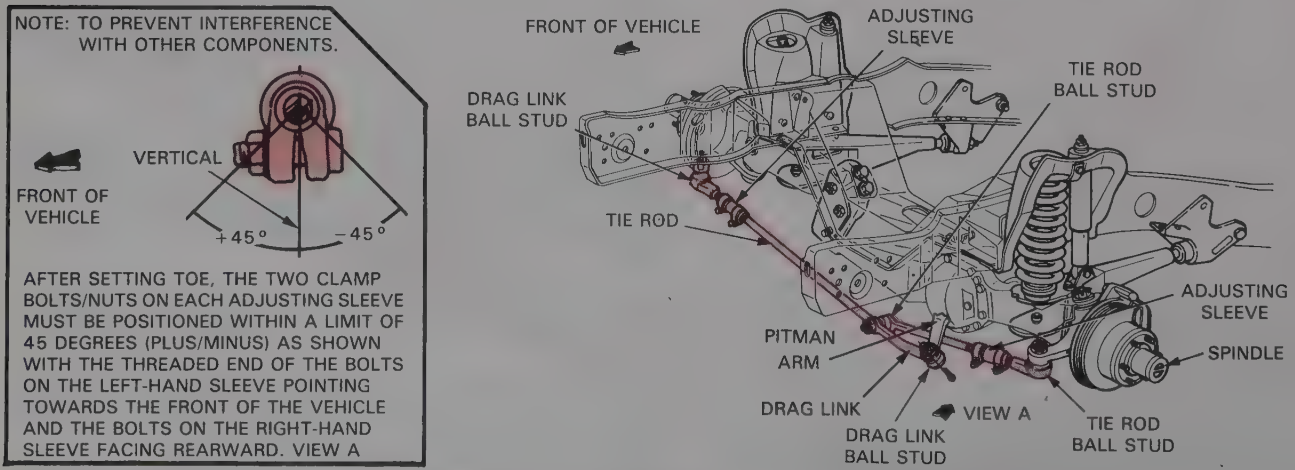
Front suspension systems generally employ either coil springs, leaf springs, torsion bars, or MacPherson struts.

A coil spring, mounted between the UPPER suspension arm and body is pictured in Fig. 33-68. Another method of arranging the coil spring is shown in Fig. 33-69. A MacPherson strut type is shown in Fig. 33-70.

A torsion bar (long spring steel rod) front suspension system is shown in Fig. 33-71. When the lower arm moves upward, it twists the torsion bar. Another torsion bar arrangement, called "transverse mounting," is illustrated in Fig. 33-72. The bars go across the width of the chassis and back to the control arms. This setup eliminates the need for strut rods.

BALL JOINT CONSTRUCTION

The main load-carrying (supports vehicle weight) ball joint design varies somewhat. Fig. 33-73 shows one


VERTICAL
FRONT OF VEHICLE
+45°
−45°
FRONT OF VEHICLE
ADJUSTING SLEEVE
TIE ROD BALL STUD
DRAG LINK BALL STUD
TIE ROD
ADJUSTING SLEEVE
SPINDLE
PITMAN ARM
DRAG LINK
VIEW A
DRAG LINK BALL STUD
TIE ROD BALL STUD

NOTE: TO PREVENT INTERFERENCE WITH OTHER COMPONENTS.

AFTER SETTING TOE, THE TWO CLAMP BOLTS/NUTS ON EACH ADJUSTING SLEEVE MUST BE POSITIONED WITHIN A LIMIT OF 45 DEGREES (PLUS/MINUS) AS SHOWN WITH THE THREADED END OF THE BOLTS ON THE LEFT-HAND SLEEVE POINTING TOWARDS THE FRONT OF THE VEHICLE AND THE BOLTS ON THE RIGHT-HAND SLEEVE FACING REARWARD. VIEW A

Fig. 33-66. A steering linkage arrangement used on a four-wheel drive vehicle. Study this arrangement carefully. The pitman arm transfers the steering gear movement through the drag link and tie rod to the spindles. (Ford)

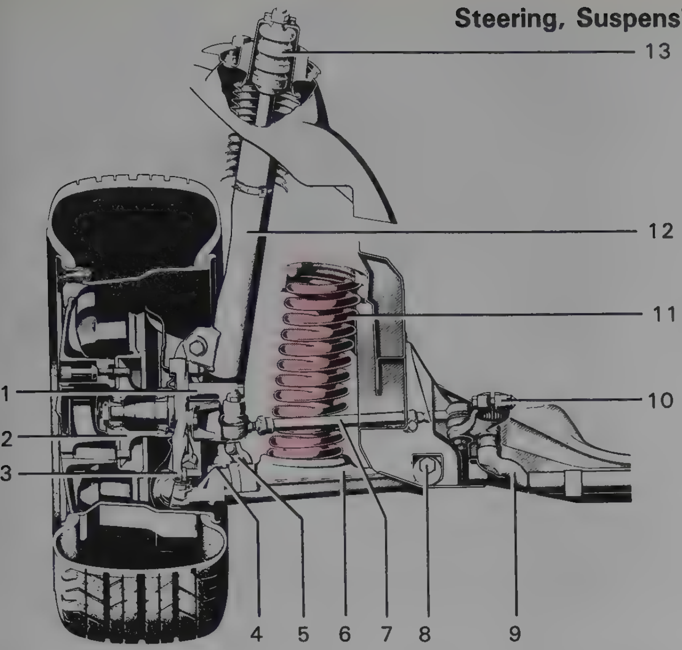

13
12
11
10
1
2
3
4
5
6
7
8
9

Fig. 33-69. One form of coil spring front suspension. 1—Steering knuckle. 2—Wheel hub. 3—Steering knuckle. 4—Stabilizer bar. 5—Stabilizer bar bushing. 6—Control arm. 7—Tie rod. 8—Alignment eccentric bolt. 9—Drag link. 10—Pitman arm. 11—Coil spring. 12—Shock absorber. 13—Polyurethane bump stop. (Mercedes-Benz)

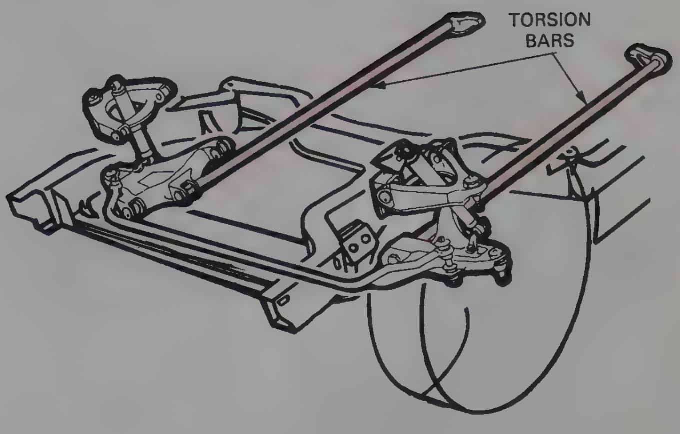

TORSION BARS

Fig. 33-71. A torsion bar front suspension. These bars run parallel with vehicle. (Moog)

by using a coil spring or rubber pressure ring. This preloading will keep the joint bearing surfaces in constant contact, Fig. 33-74.

Depending upon arrangement, both types of ball joints can be placed under either TENSION

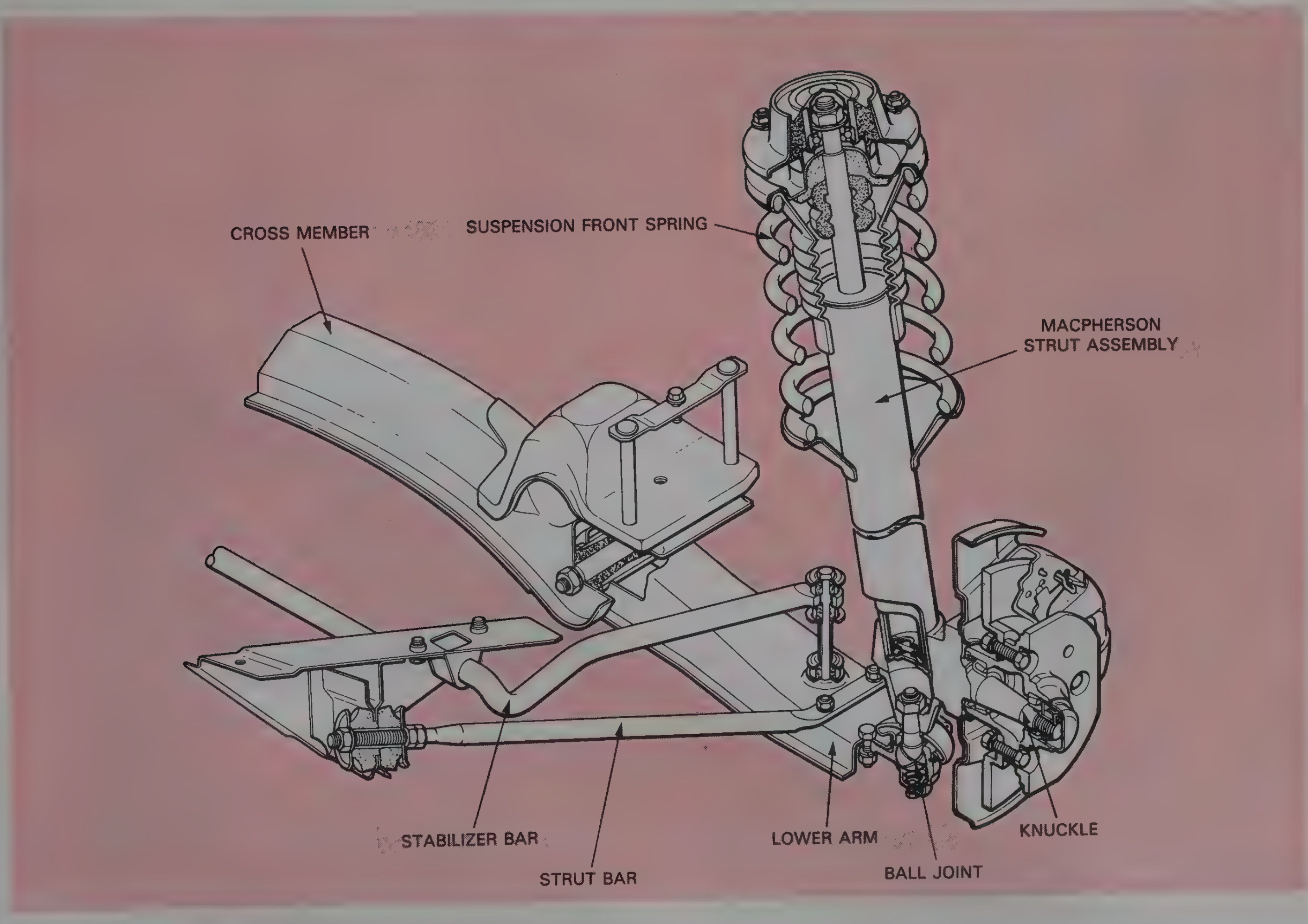

CROSS MEMBER
SUSPENSION FRONT SPRING
MACPHERSON STRUT ASSEMBLY
STABILIZER BAR
STRUT BAR
LOWER ARM
BALL JOINT
KNUCKLE

Fig. 33-70. Cutaway view of one particular MacPherson strut front suspension. (Chrysler)

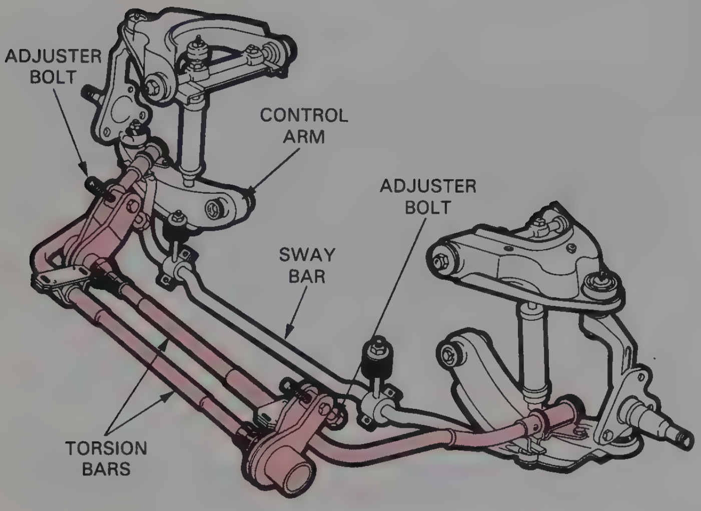

ADJUSTER BOLT
CONTROL ARM
ADJUSTER BOLT
SWAY BAR
TORSION BARS

Fig. 33-72. Torsion bars arranged in a transverse manner. Note that each bar has its own adjustment bolt. (Moog)

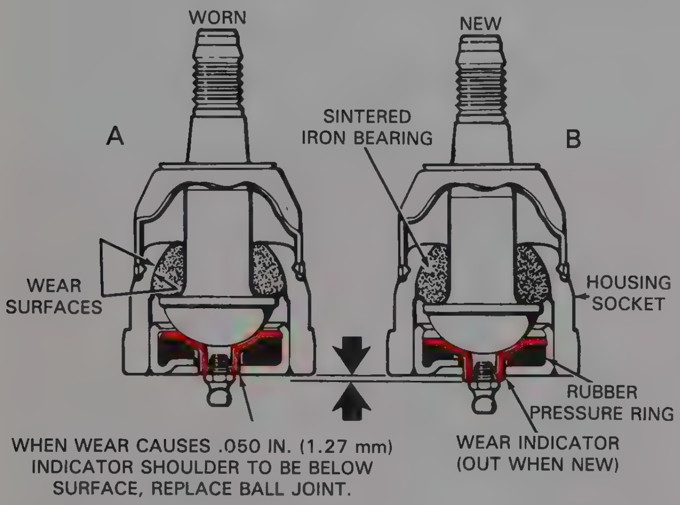

WORN
NEW
A
B
SINTERED IRON BEARING
WEAR SURFACES
HOUSING SOCKET
RUBBER PRESSURE RING
WHEN WEAR CAUSES .050 IN. (1.27 mm) INDICATOR SHOULDER TO BE BELOW SURFACE, REPLACE BALL JOINT.
WEAR INDICATOR (OUT WHEN NEW)

Fig. 33-73. One type of load carrying ball joint. Note wear indicator. (Oldsmobile)

LOADING (forces attempt to pull joint apart) or COMPRESSION LOADING (forces attempt to compress joint). Fig. 33-75 illustrates one basic arrangement in which both joints are tension loaded. Note that the lower joint is the main load-carrying joint.

A second arrangement tension loads the FOLLOWER JOINT (upper joint in this case) and compression loads the main LOAD-CARRYING JOINT (lower joint in this case). Note that the coil spring is between the lower suspension arm and frame in both Figs. 33-75 and 33-76.

A third arrangement (coil spring placed between the upper suspension arm and body) places the MAIN JOINT at the top. In this setup, the main joint is compression loaded. The follower joint is tension loaded. See Fig. 33-77.

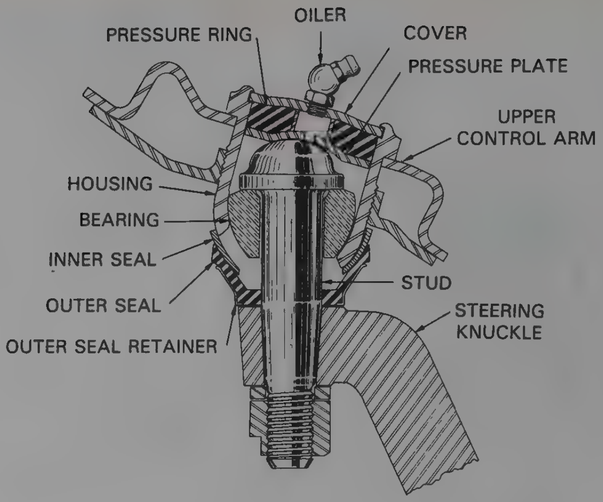

OILER
PRESSURE RING
COVER
PRESSURE PLATE
UPPER CONTROL ARM
HOUSING
BEARING
INNER SEAL
OUTER SEAL
OUTER SEAL RETAINER
STUD
STEERING KNUCKLE

Fig. 33-74. Typical follower (nonload-carrying ball joint). Note rubber pressure ring used to provide constant loading.

BALL JOINT WEAR

Excessive ball joint wear will alter front wheel alignment and can cause hard steering, shimmy, and tire wear.

Although the follower joint does wear, main load-carrying joint will usually reach the worn stage first.

Check both joints. If the follower shows any discernable looseness, replace it. The main joint clearance (play) should not exceed manufacturer's specifications.

CHECKING BALL JOINT WEAR

To check ball joints for wear, they must be properly unloaded (pressure removed).

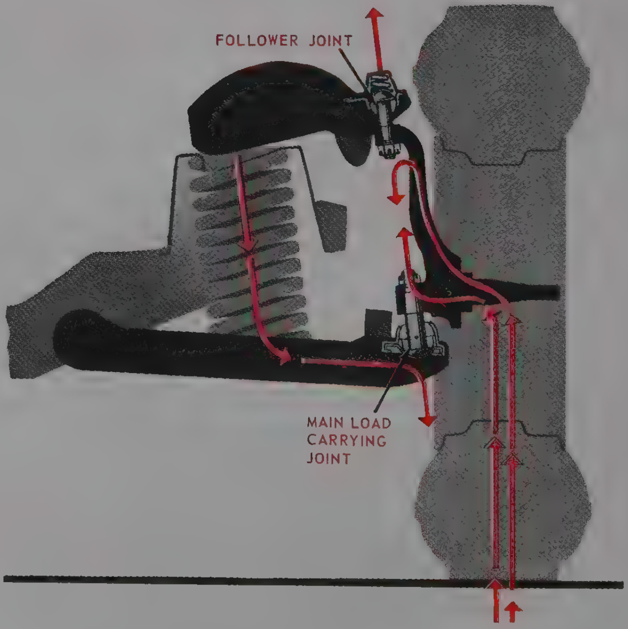

FOLLOWER JOINT
MAIN LOAD CARRYING JOINT

Fig. 33-75. This arrangement tension loads ball joints. Main load carrying joint is at the bottom. (Moog)

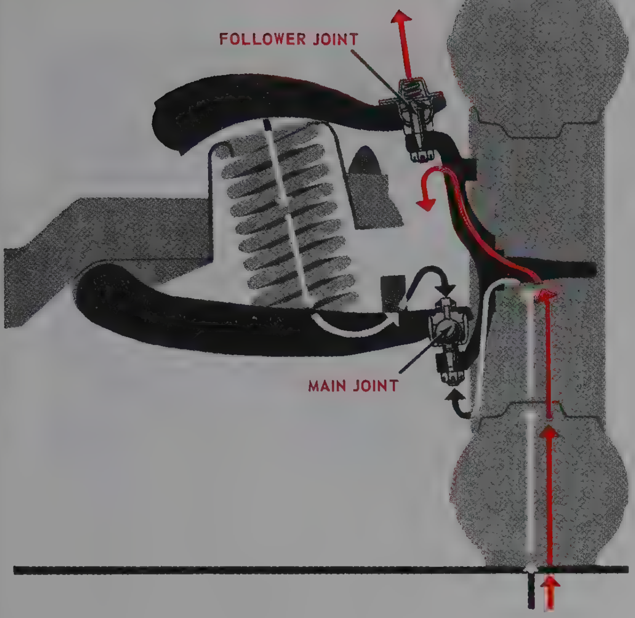

FOLLOWER JOINT
MAIN JOINT

Fig. 33-76. This setup tension loads the follower joint and compression loads the main joint. (Moog)

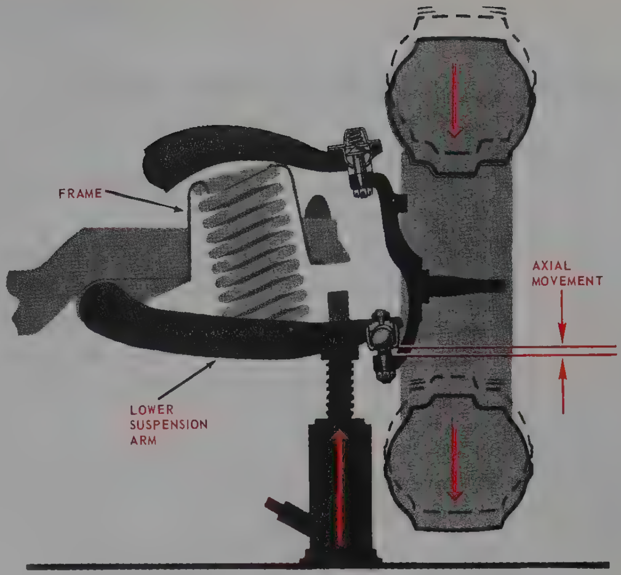

FRAME
AXIAL MOVEMENT
LOWER SUSPENSION ARM

Fig. 33-78. Unloading ball joints. When coil spring is mounted between lower suspension arm and frame, place jack under LOWER SUSPENSION ARM.

When the coil spring is placed between the lower suspension arm and the frame, Fig. 33-78, place the jack under the lower suspension arm. When the jack is raised high enough to provide clearance between the tire and floor, the ball joints will be unloaded. When a torsion bar front suspension is used, place the jack as shown in Fig. 33-78.

To unload the ball joints when the coil spring is placed between the top suspension arm and car body, install a support wedge. Place the jack under the frame. The support wedge will prevent the coil spring from loading the joint. See Fig. 33-79.

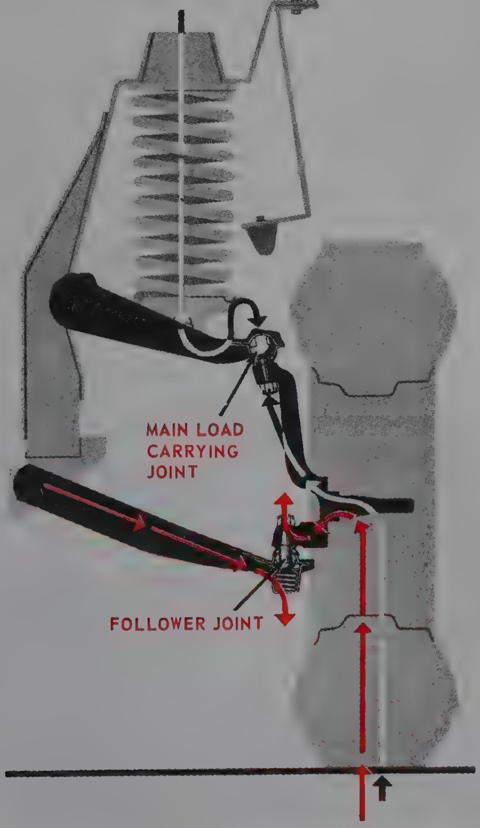

MAIN LOAD CARRYING JOINT
FOLLOWER JOINT

Fig. 33-77. This installation places main load-carrying joint at top.

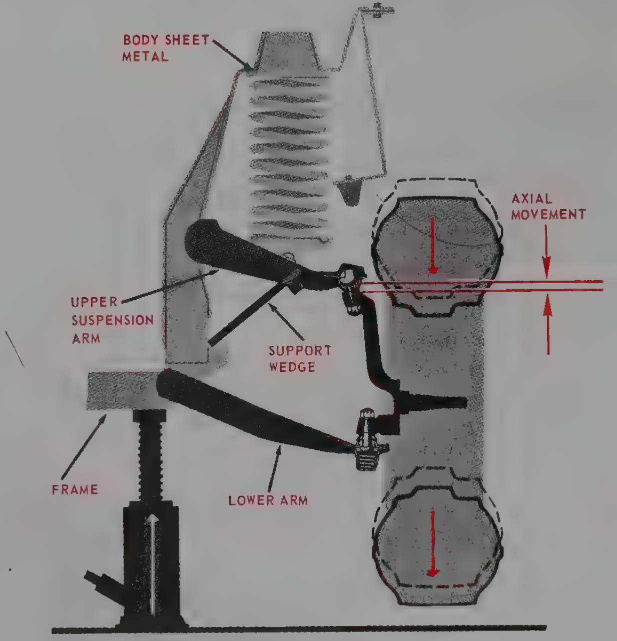

BODY SHEET METAL
AXIAL MOVEMENT
UPPER SUSPENSION ARM
SUPPORT WEDGE
FRAME
LOWER ARM

Fig. 33-79. To unload ball joints when coil spring is placed between upper suspension arm and body, place a SUPPORT WEDGE between upper arm and frame. Raise tire free of floor by placing jack AGAINST FRAME. Do not jack against lower arm.

MEASURING MAIN BALL JOINT CLEARANCE

After properly unloading the ball joint, Figs. 33-78 and 33-79, the amount of wear may be determined in one of two ways.

Some manufacturers recommend checking joint play by measuring the axial movement. Axial movement is the UP and DOWN movement of the wheel and tire assembly. See A in Fig. 33-80. Other makers specify testing for excessive clearance by measuring tire sidewall movement. See B in Fig. 33-80.

Specifications vary for what constitutes excessive ball joint play, depending upon joint design. Follow manufacturer's specifications.

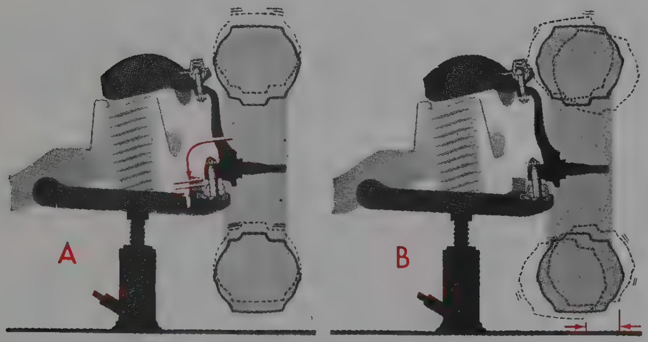


Fig. 33-80. Two methods of measuring ball joint wear. A—Axial movement. B—Tire sidewall movement.

REMOVAL AND INSTALLATION OF MAIN LOAD CARRYING BALL JOINT

Raise car and place jack stands under lower suspension arm if the coil spring is mounted between the lower control arm and the frame, Fig. 33-78. If the spring is mounted between the top of the upper suspension arm and the body, Fig. 33-79, place a support wedge into position before raising the car. Where the support wedge is used, jack stands under the lower arms will not be necessary.

DANGER! When the coil spring is mounted between the lower arm and the frame, removal of either the upper or lower ball joint will, unless jack stands are in place against the lower suspension arms, allow the spring to propel the lower suspension arm downward with LETHAL FORCE. Always place jacks or jack stands beneath the lower arms when so needed.

Remove the cotter key from the ball joint stud nut. Loosen the stud nut several turns. In some cases, the regular nut is removed and a standard hex nut is turned on to within two or three threads of the steering spindle or knuckle, Fig. 33-81.

A special removal tool may be placed between the ends of the upper and lower stud ends. Turn the tool to apply pressure to the ball stud. When the stud is under pressure, strike the steering spindle sharply with a hammer to free the stud in the spindle or knuckle body. See Fig. 33-81.

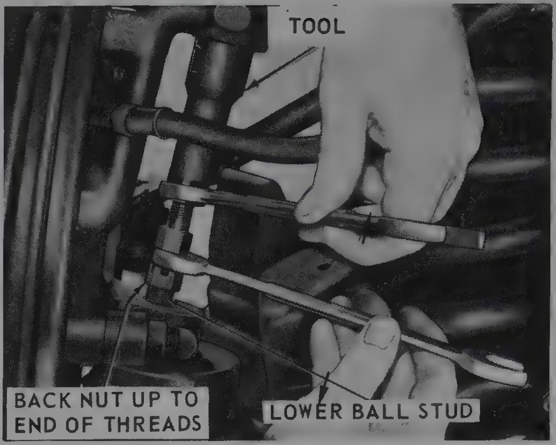


Fig. 33-81. Using a special removal tool to apply pressure to lower ball stud. (G.M.C.)

Never try to force the ball stud out of the spindle body by using heavy pressure with a tool similar to that shown in Fig. 33-81. To do so would distort the spindle. Always rap spindle until stud is free — while stud is under moderate pressure only.

The tension loaded main ball joint in Fig. 33-82 is being removed by rapping the spindle body with a hammer.

When the ball stud is loose, remove the tool and stud nut. Make certain the lower arm is securely supported.

Drop arm slowly by lowering jack until ball joint is clear. Jack should be parallel with the suspension arm, as in Fig. 33-83. If necessary, disconnect lower suspension arm pivot shaft and remove arm.

Some ball joints are screwed in place while others may be riveted, pressed, bolted, or welded.

Where threaded, remove joint by unscrewing. Clean

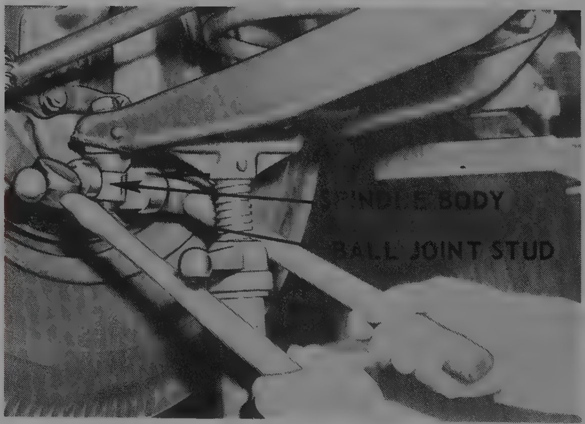


Fig. 33-82. Removing a ball joint stud by hammering spindle body. (Chevrolet)

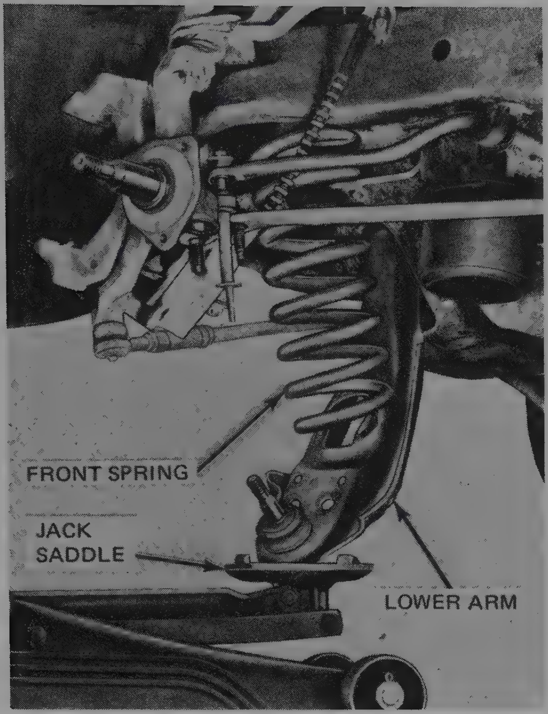

FRONT SPRING
JACK SADDLE
LOWER ARM

Fig. 33-83. Lowering lower suspension arm to clear ball joint. Be careful! Follow all safety rules. Springs are dangerous. (Ford)

arm and threads. Then install new joint. Torque to specifications.

If the joint is riveted to the arm, drill through the rivets with the specified size drill. Cut off the rivet heads and drive rivets out. A power chisel, Fig. 33-84, makes rivet head removal easy. Some manufacturers recommend drilling off the rivet heads that secure the joint. This procedure is illustrated in Fig. 33-85.

Clean arm thoroughly. Install ball joint. Instead of inserting new rivets, use the bolts supplied. Torque bolts to specifications. Use only special bolts supplied specifically for mounting the ball joints.

Fig. 33-86 illustrates the removal and installation of a ball joint that is pressed into place.

Clean spindle body ball stud hole. Clean stud. If removed, replace suspension arm. With coil spring properly in place, raise arm with jack until ball stud passes through spindle body. Install retaining nut and torque. Install cotter pin.

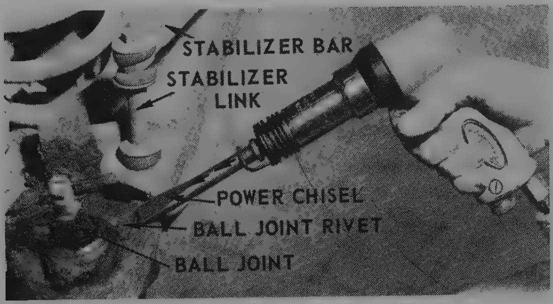

STABILIZER BAR
STABILIZER LINK
POWER CHISEL
BALL JOINT RIVET
BALL JOINT

Fig. 33-84. Cutting off ball joint rivets. (Albertson)

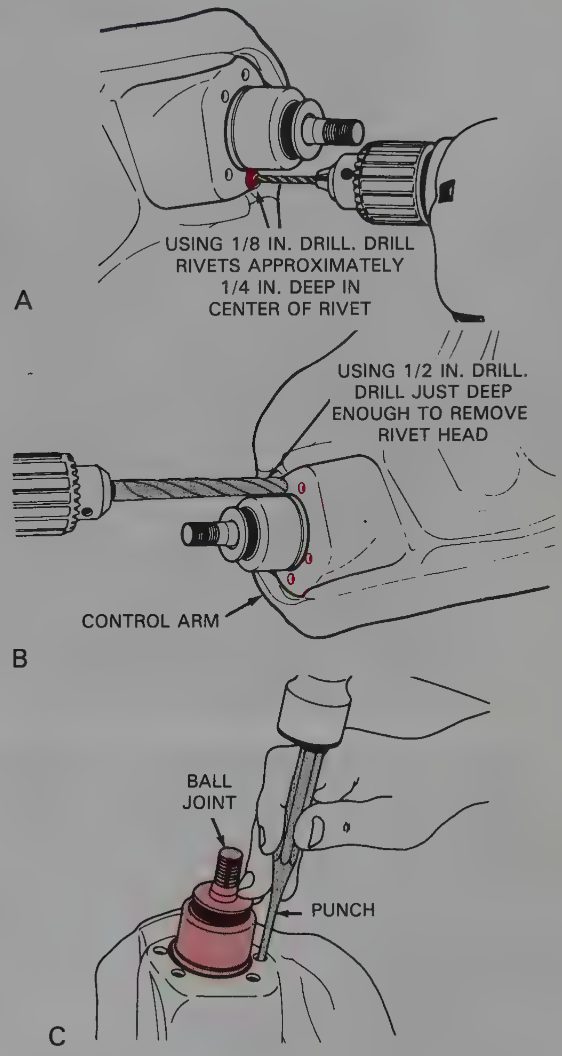

A
USING 1/8 IN. DRILL. DRILL RIVETS APPROXIMATELY 1/4 IN. DEEP IN CENTER OF RIVET
USING 1/2 IN. DRILL. DRILL JUST DEEP ENOUGH TO REMOVE RIVET HEAD
CONTROL ARM
B
BALL JOINT
PUNCH
C

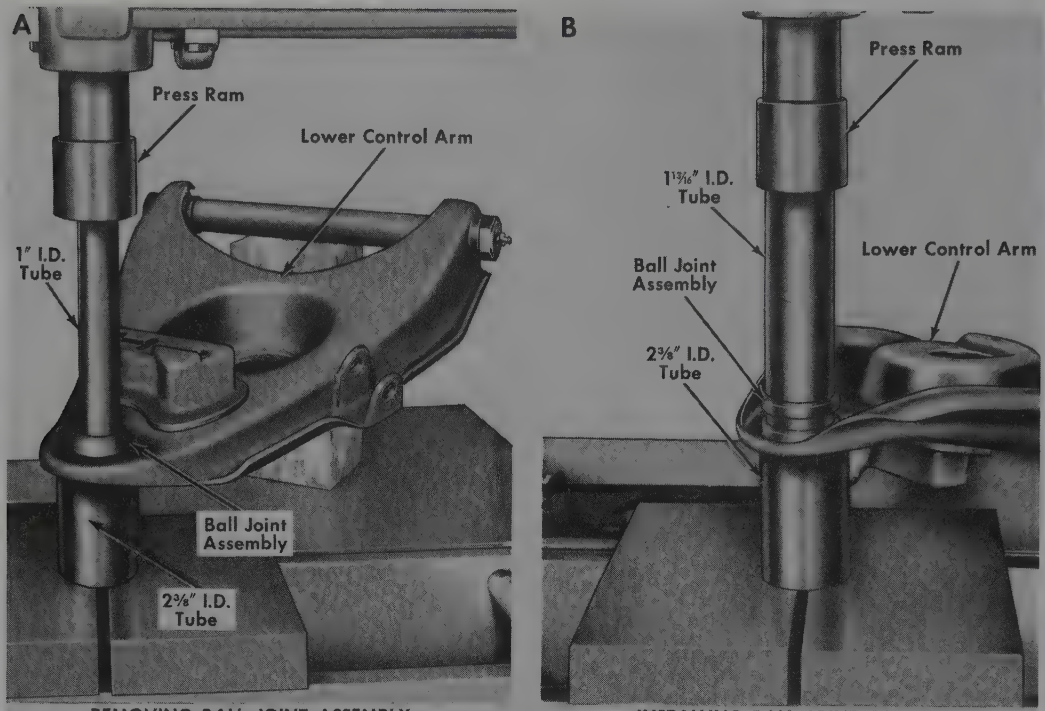
Fig. 33-85. Removing a ball joint by drilling off rivet heads. A—Drilling a 1/8 in. (3.16 mm) hole 1/4 in. (6.35 mm) deep in rivet center. B—Rivet heads have just been drilled off using a 1/2 in. (12.7 mm) bit. DO NOT drill into control arm. C—Using a punch to drift out rivets, freeing ball joint. (Buick)

Lubricate joint. If a camber eccentric is incorporated in the upper ball stud, check and adjust camber.

REMOVAL AND INSTALLATION OF FOLLOWER BALL JOINT

The general procedure involved in removing and installing a follower ball joint is quite similar to that described for the main load-carrying joint.

When the coil spring is mounted between the lower suspension arm and frame, support the lower arm. Prevent it from slamming down from spring pressure when the follower joint stud is removed.



REMOVING BALL JOINT ASSEMBLY

INSTALLING BALL JOINT ASSEMBLY

Fig. 33-86. Removal and installation of a pressed-in ball joint. (G.M.C.)

Some follower joints are welded to the suspension arm. When worn, the entire assembly must be replaced.

FRONT COIL SPRING REMOVAL AND INSTALLATION

Raise car and place jack stands under frame. Remove wheel and tire assembly. Disconnect stabilizer bar from side concerned. Remove shock absorber. Disconnect lower arm tie strut, if used. Attach safety chain.

Place a jack under the lower arm so the jack is parallel to the arm. This allows the jack to roll forward or backward to follow the movement of the suspension arm free end.

Remove lower ball joint stud as recommended under ball joint removal. Lower jack until lower suspension arm removes pressure from spring.

REMOVE SPRING. WATCH OUT WHEN REMOVING SPRING. IF IT IS SLIGHTLY LOADED (UNDER PRESSURE), IT COULD SNAP OUT VIOLENTLY. See Fig. 33-87.

To install a spring, reverse the above procedure. Make certain that spring insulators, where used, are in place and that the spring is correctly installed. Specifications usually call for the spring end to be in a certain location. Fig. 33-88 illustrates correct spring end location for one car.

When arm is raised, make sure that the spring does not rotate out of position. Raise until ball joint stud passes through spindle body. Install stud nut, torque, and insert cotter pin. Install shock absorber, stabilizer bar, and tie strut where used.

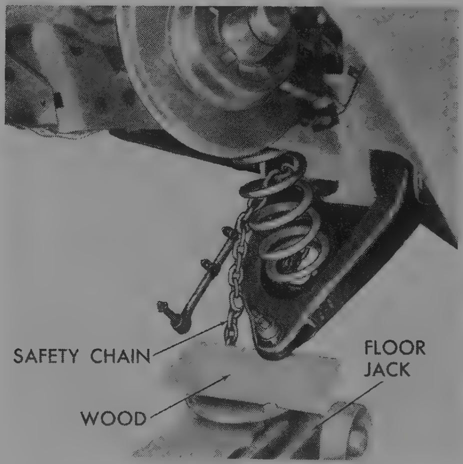


Fig. 33-87. Lowering suspension control arm to free coil spring. Note use of a safety chain to prevent spring from flying out. (Chevrolet)

Use extreme care when removing and installing springs. A little carelessness can cause a serious accident.

SPRING COMPRESSORS ARE SOMETIMES NEEDED

Some coil springs cannot be removed or installed without the use of a spring compressor. The compressor is inserted into the spring and the draw bolt tightened.

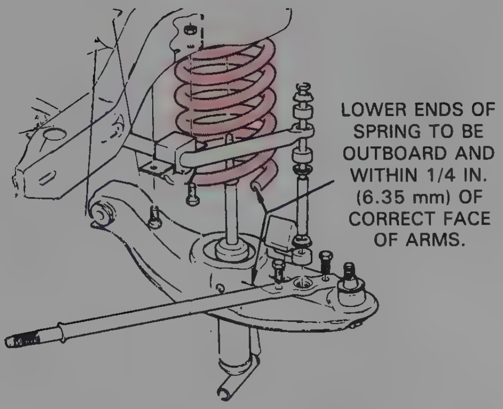

LOWER ENDS OF SPRING TO BE OUTBOARD AND WITHIN 1/4 IN. (6.35 mm) OF CORRECT FACE OF ARMS.

Fig. 33-88. Correct spring end location for one car. (Buick)

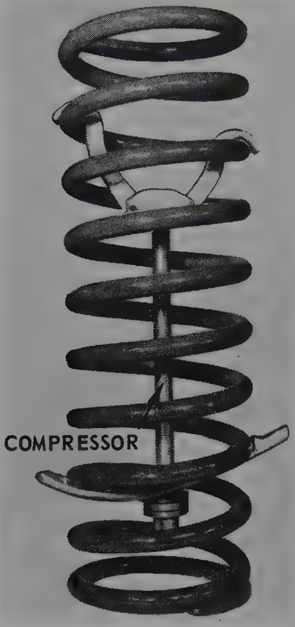
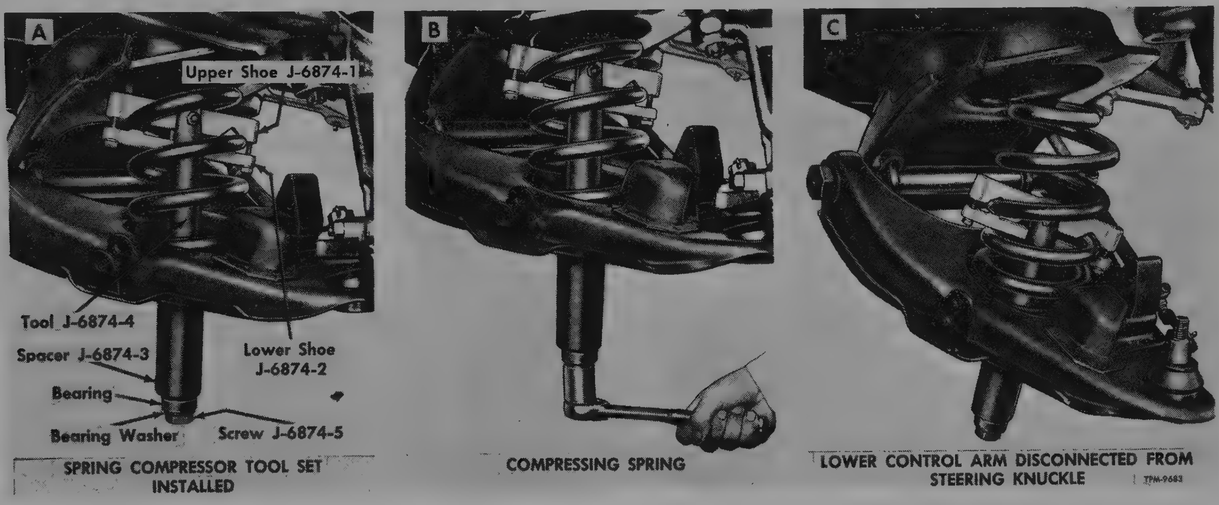


Fig. 33-89. Typical spring compressor in position. (Branich)

This pulls the coils together to both shorten and unload the spring, making removal possible. Fig. 33-89 illustrates one type of spring compressor in position.

A somewhat different type of spring compressor is shown in Fig. 33-90. Note how compressor is installed at A and then tightened at B. Arm may then be lowered to free spring, C.



SPRING COMPRESSOR TOOL SET INSTALLED

COMPRESSING SPRING

LOWER CONTROL ARM DISCONNECTED FROM STEERING KNUCKLE

Fig. 33-90. Using a spring compressor to facilitate coil spring removal. (G.M.C.)

Make sure the compressor is installed correctly and that the draw bolt is secure.

FRONT COIL SPRING REMOVAL AND INSTALLATION — MACPHERSON STRUT

There are two basic MacPherson strut coil spring arrangements. One type uses the coil spring mounted on the lower control arm. See Fig. 33-91. The other (which will be covered here) utilizes the coil spring mounted so that it surrounds the damper (shock). Look at Fig. 33-92.

Place the vehicle on a hoist or jack stands. Raise the hood. Locate the strut bolts (generally three) on each inner fender well at the top. Mark one bolt on each side of the vehicle. Leave one bolt or nut attached until the bottom of the strut is disconnected. Remove the tire and wheels. Disconnect the lower mounting bolts or ball joint depending on attachment method used.

Disconnect the brake assembly and/or line. Support the strut so it will not fall. Remove the nut or bolt which was left connected on the fender well. Remove the strut and mount it in a special holding fixture or vise. See Fig. 33-92.

Attach a coil spring compressor. Compress the spring until tension is removed from the spring retainer, rebound bumper, and other parts. Loosen strut rod nut while holding strut rod. Refer to Fig. 33-93.

Pull off rebound bumper, retainer, and other parts.

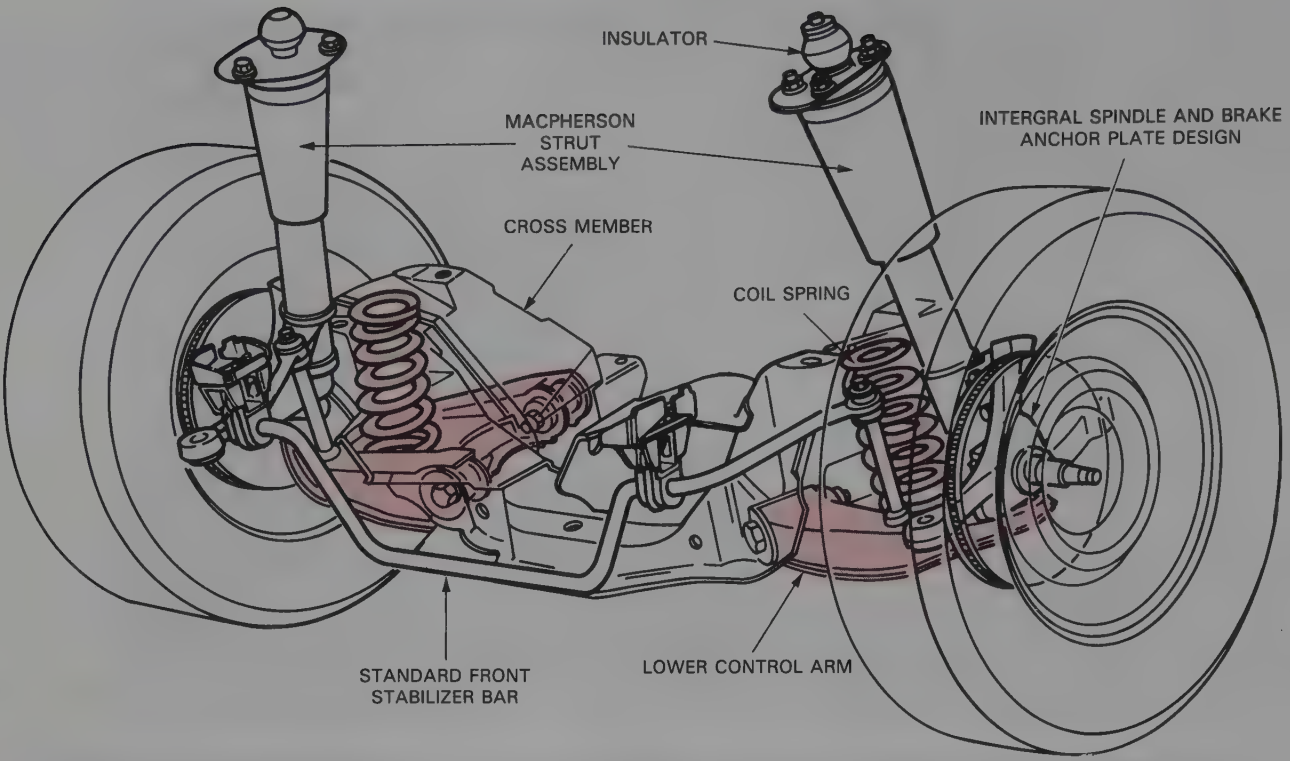

INSULATOR
MACPHERSON STRUT ASSEMBLY
INTERGRAL SPINDLE AND BRAKE ANCHOR PLATE DESIGN
CROSS MEMBER
COIL SPRING
STANDARD FRONT STABILIZER BAR
LOWER CONTROL ARM

Fig. 33-91. MacPherson strut type front suspension that locates springs between frame and lower control arm. Compare to Fig. 33-70. (Ford)

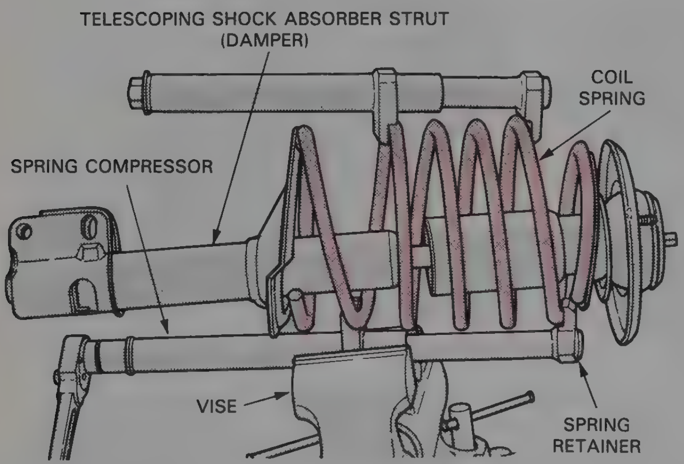

TELESCOPING SHOCK ABSORBER STRUT (DAMPER)
COIL SPRING
SPRING COMPRESSOR
VISE
SPRING RETAINER

Fig. 33-92. Coil spring being compressed with special tools. Give each tool an equal number of turns. Note top compressor has squeezed spring and bottom compressor is being turned to match. (Chrysler)

Lift off the coil spring. Be sure to mark spring top and bottom (if different). Also label which side of the vehicle it was removed from.

If spring requires replacement (sagging, bent, broken), carefully relieve compressing tool tension. Remove spring and discard it. Place new, approved spring in tool and compress.

Reinstall parts in reverse order of disassembly.

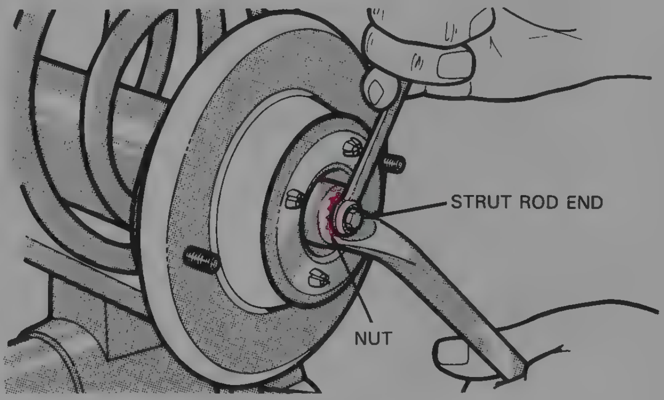

STRUT ROD END
NUT

Fig. 33-93. Removing strut rod nut while holding strut rod. Be sure spring tension HAS BEEN RELIEVED before completely removing nut. (Plymouth)

Torque all fasteners to specifications. Reconnect brake lines. Bleed if necessary. Check front alignment and road test.

WARNING: As with all springs under tension, BE EXTREMELY CAREFUL. They can fly off with lethal force!

TORSION BAR REMOVAL

Raise vehicle by the frame so that the front suspension arms are in the full rebound (down) position. On some installations, the rubber rebound snubber must be removed to permit the upper arm to reach the full rebound position.

Turn the torsion bar anchor bolt to remove all tension from the torsion bar. Mark the torsion bars (indicate right and left side) to avoid confusion and ease installation. Fig. 33-94 illustrates a typical adjustable torsion bar rear support. Note adjusting bolt.

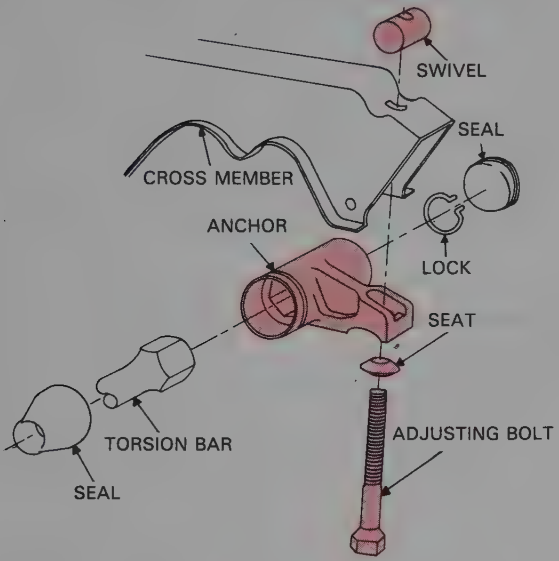

SWIVEL
SEAL
CROSS MEMBER
ANCHOR
LOCK
SEAT
TORSION BAR
ADJUSTING BOLT
SEAL

Fig. 33-94. Typical adjustable torsion bar rear support. (Chrysler)

A torsion bar, rear support, upper and lower control arms, and strut rod are pictured in Fig. 33-95.

A detailed view of one method of attaching the torsion bar to the lower suspension arm is shown in Fig. 33-96.

Disengage lock ring and plug from rear anchor or support. Clean off torsion bar ahead of balloon seal, Fig. 33-94. Disengage seal from anchor and carefully slide seal part way up the bar.

Slide the bar backward far enough to disengage the front hex from the suspension arm. Pull bar to one side and then remove from the front. Some installations permit sliding the bar backwards out through the rear anchor.

If the bar is stuck in the anchors, use a special

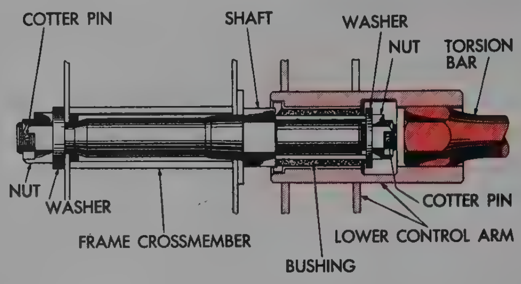

COTTER PIN
SHAFT
WASHER
NUT
TORSION BAR
NUT
WASHER
FRAME CROSSMEMBER
BUSHING
COTTER PIN
LOWER CONTROL ARM

Fig. 33-96. Lower suspension arm, arm pivot shaft, section of torsion bar. Note how hexagonal head of torsion bar fits into lower suspension (control) arm.

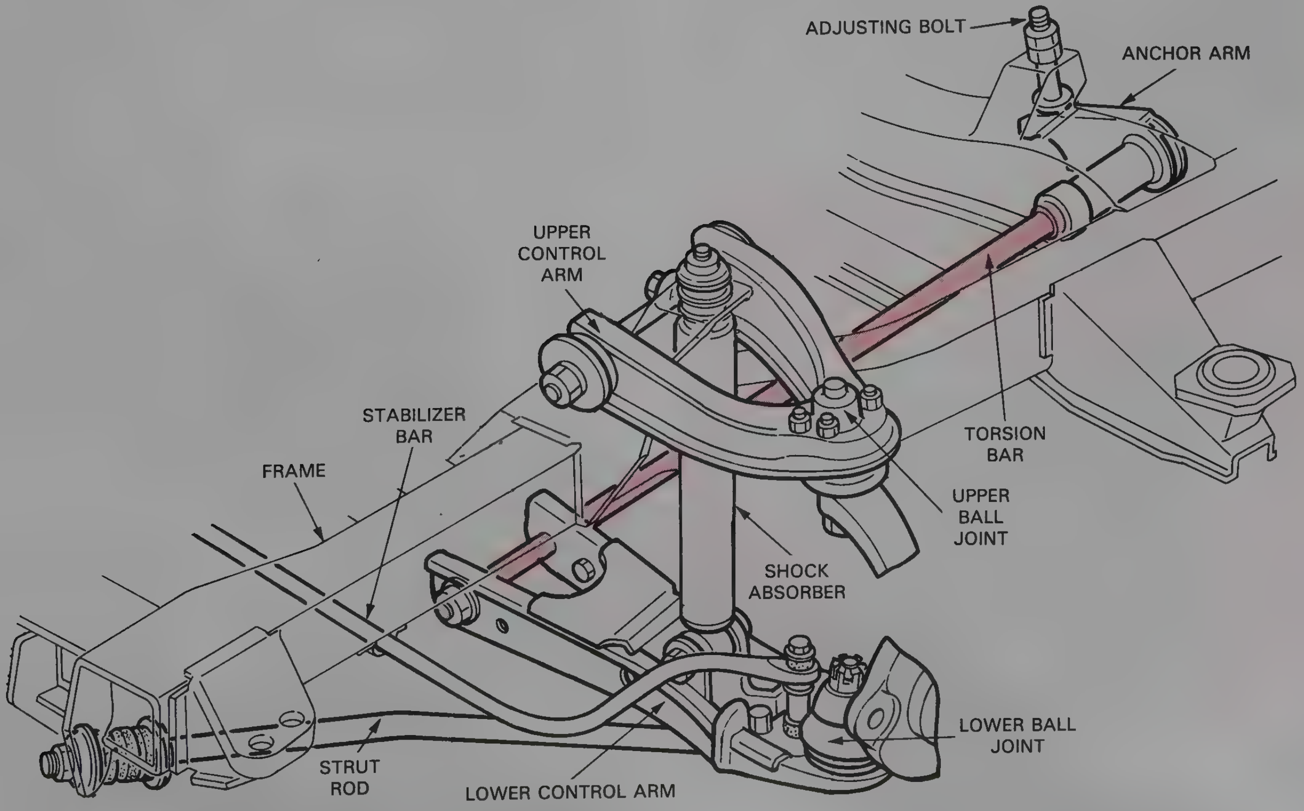

ADJUSTING BOLT
ANCHOR ARM
UPPER CONTROL ARM
STABILIZER BAR
FRAME
TORSION BAR
UPPER BALL JOINT
SHOCK ABSORBER
LOWER BALL JOINT
STRUT ROD
LOWER CONTROL ARM

Fig. 33-95. One particular torsion bar setup. (Nissan)

clamp-on striking pad. The pad is clamped to the bar and struck with a hammer to loosen the bar. Never use heat on the bar or on front and rear anchors. Do not hammer on the bar or use a pipe wrench. Avoid denting or nicking the surface.

CLEAN AND INSPECT TORSION BAR

Clean and inspect the bar. Remove any small nicks or burrs by filing and polishing with fine emery cloth. Paint the polished section with rust resistant primer. Like all springs, a torsion bar can crack if nicked.

Clean, inspect, and lubricate the rear anchor swivel and adjusting bolt. Replace if needed. Clean front and rear bar anchor hex holes.

TORSION BAR INSTALLATION

Make sure left and right-side bars are NOT mixed up. Bar must be clean. Slide bar through rear anchor. Slip a NEW balloon seal on the bar. Coat both ends of the torsion bar with multipurpose grease. Insert bar front hex end into lower suspension arm. Install rear anchor lock ring and plug. Fill opening around front of rear anchor with multipurpose grease and carefully position the balloon seal. Load the bar a small amount with the adjusting screw.

Place vehicle on the floor and adjust front height by turning torsion bar adjusting bolt. Bounce car vigorously and recheck height.

Fig. 33-97 illustrates the measuring points for checking the front and rear suspension height for a specific car equipped with independent front and rear suspension.

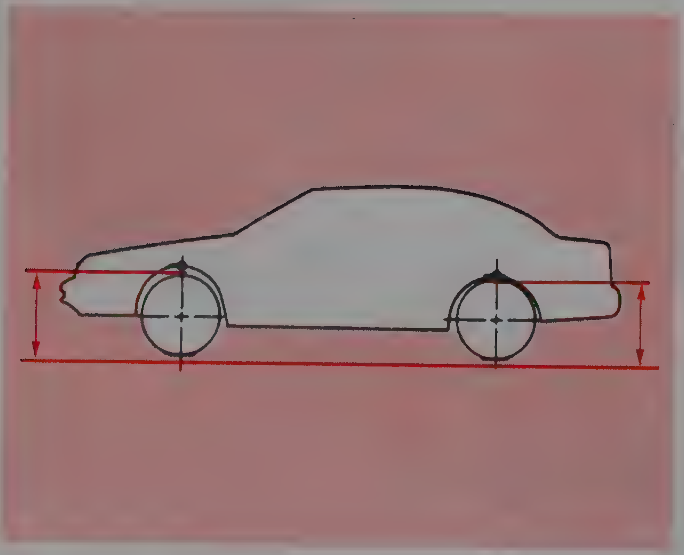


Fig. 33-97. Checking front and rear suspension height. Bounce vehicle up and down several times before taking measurements. (Nissan)

SUSPENSION ARM REMOVAL

Disconnect shock absorber, stabilizer bar, tie strut, and other parts as needed. Block lower suspension arm with a jack. Remove ball joint stud from arm. (Refer to sections on ball joint and coil spring removal earlier in this chapter.)

When removing the suspension arm mounting shaft, mark location of camber and caster shims. If arm mounting shaft is slotted, center punch location of shaft in relation to the frame to assist in rough resetting of camber and caster.

When removing tie strut (where used), do not move rear locknut (nut on lower arm side of rubber strut bushing).

REPLACING SUSPENSION ARM BUSHINGS

When one is worn, always replace BOTH bushings in the upper arm. If the lower arm utilizes two bushings, replace both.

When installing a new inner shaft, use new bushings.

To facilitate bushing removal when using a press, bolt a tool, similar to that shown in Fig. 33-98, to the inner shaft. Note that two tools are used in this setup.

Remove the fasteners and washers from the end of the bushings. Apply penetrating oil around the bushing. Set the arm up in a press with a bushing receiving tool under the lower bushing. Use a narrow adapter to reach through the upper bushing. Press downward on the inner shaft until the lower bushing is removed.

Reverse the arm and remove the other bushing, Fig. 33-98.

If threaded type bushings are used, they may be removed by unscrewing.

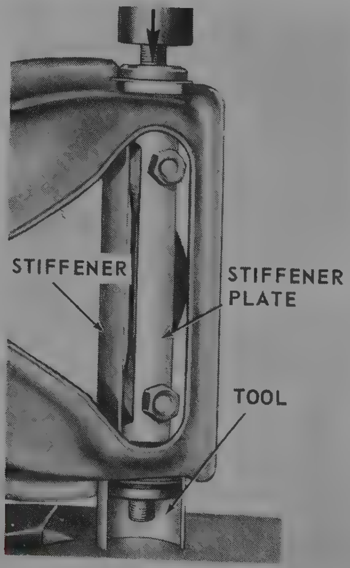


Fig. 33-98. Removing upper suspension arm bushings — pressed in type. (Ford)

Clean the suspension arm and check for cracks, heavy dents, springing, and other problems. Check inner shaft for excessive wear. Fig. 33-99 illustrates a typical upper suspension arm completely disassembled.

To install new bushings, place the inner shaft into the arm. Install a spacer tool, as pictured in Fig. 33-100, to prevent the arm from being bent.

Start bushings into place. Make certain bushings are on the correct ends. Set arm up in a press. Using bushing pressing tools, force the bushings into place, Fig. 33-101.

Install outer washers and fasteners. Torque to specifications.

If threaded bushings are used, make certain the inner shaft is correctly centered in the arm. See Fig. 33-102.

In the case of the lower suspension arm that utilizes a tie strut, there is only one inner bushing. Note how a small spacer block, Fig. 33-103, is used to prevent arm distortion while removing the lower arm bushing. The spacer, when required, should also be used when installing the bushing.

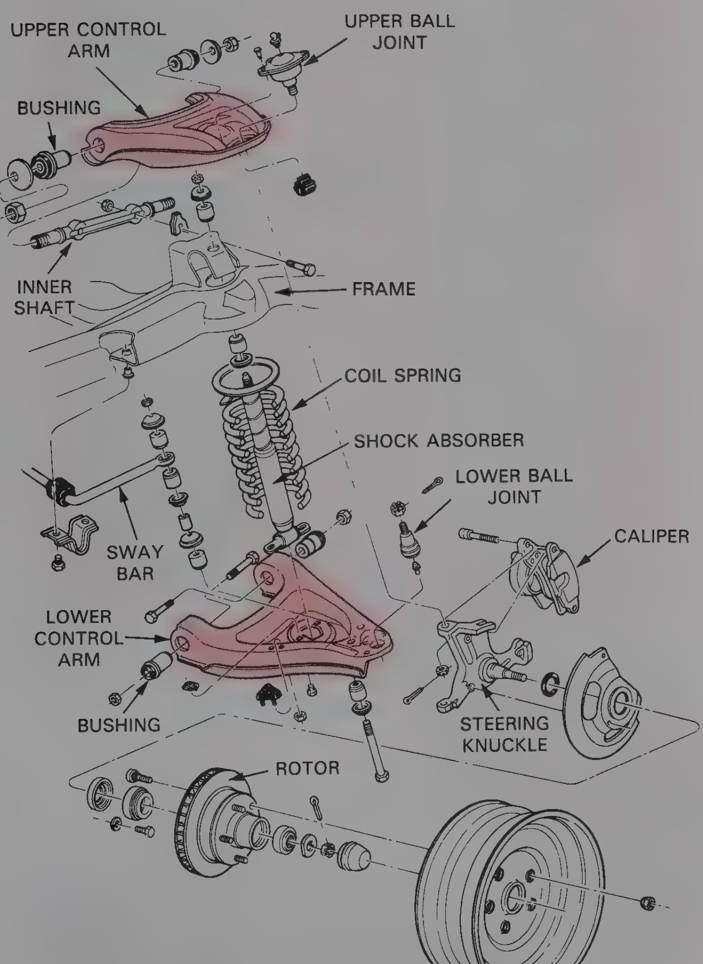

UPPER CONTROL ARM
UPPER BALL JOINT
BUSHING
INNER SHAFT
FRAME
COIL SPRING
SHOCK ABSORBER
LOWER BALL JOINT
CALIPER
SWAY BAR
LOWER CONTROL ARM
BUSHING
STEERING KNUCKLE
ROTOR

Fig. 33-99. Exploded view of an upper and lower control arm arrangement, as used by one maker. (Chevrolet)

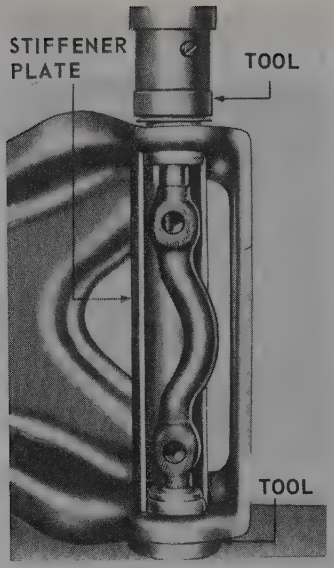

STIFFENER PLATE
TOOL
TOOL

Fig. 33-100. Pressing upper suspension arm bushings into place. Note use of stiffener plate to prevent arm distortion.

SHOCK ABSORBER

To produce a smooth, controlled, and safe ride, the shock absorbers must be in good condition. When a shock is operating properly, it will control spring

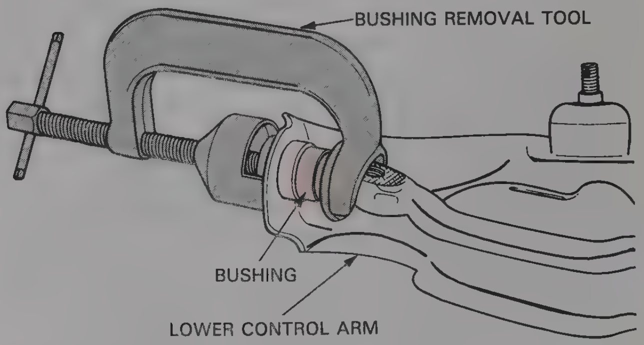

BUSHING REMOVAL TOOL
BUSHING
LOWER CONTROL ARM

Fig. 33-101. Replacing a lower control arm bushing with special tool. (Ford)

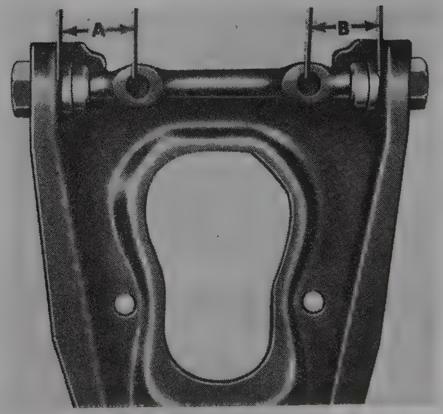


Fig. 33-102. When threaded bushings are used, make sure inner shaft is centered properly.

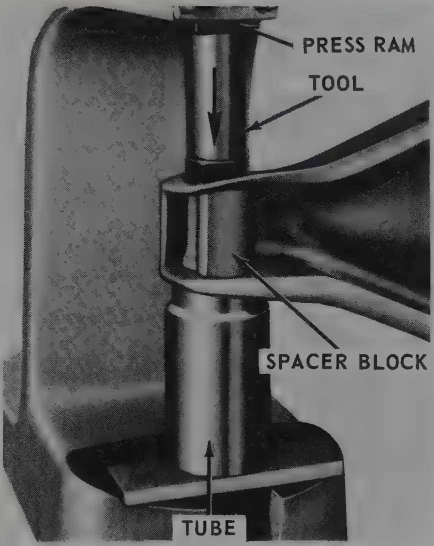


Fig. 33-103. Removing lower suspension arm bushing. Note spacer block. (Lincoln)

oscillation, spring rebound, and rate of spring compression. When straddle mounted (mounted at an angle) body sway and lean are also minimized.

The commonly used shock is of the telescopic (airplane) type. Typical telescopic shock action is illustrated in Fig. 33-104. Note shock extension in (1). The rebound stroke pulls the piston upward, forcing fluid in A through the valve in the piston to compartment B. Vacuum action draws fluid through the base valve from reservoir C.

Fig. 33-104 (2) shows the action during the compression stroke. The piston is forced downward. This causes fluid to be forced through the piston valve into compartment A, and through the base valve into reservoir C. Area D is air space above the fluid.

The fluid passing through the various valves or orifices slows down the movement of the piston, thus placing a damping action on the movement of the springs. See Fig. 33-104.

Some shock absorbers have adjusting devices to control the amount of damping action. Some are controlled by a manual valve that may be turned from inside the car. Others have an automatic control while others must be adjusted at the time of installation.

Most shocks have valving that is calibrated for an average load-road condition for a given car and are NOT adjustable. Most shocks cannot be repaired.

CHECKING SHOCK ABSORBERS AND STRUT DAMPERS

Inspect each shock absorber or MacPherson strut damper for signs of fluid leakage. Service or replace them if leaks are found.

Check the condition of the rubber bushings. Shocks or dampers can rattle, pound, and cause poor control if the mounting bushings are worn or missing. Also inspect mounting brackets and fasteners.

Grasp shock or damper and try to shake sideways and up and down, Fig. 33-105. Bounce each corner of the car and compare shock action. Bounce vigorously and quickly release at bottom of the down stroke. Shocks or dampers in good condition will allow about one "free" bounce and will then stop any further movement. This is illustrated in Fig. 33-106.

If shock action is doubtful, service or replace.

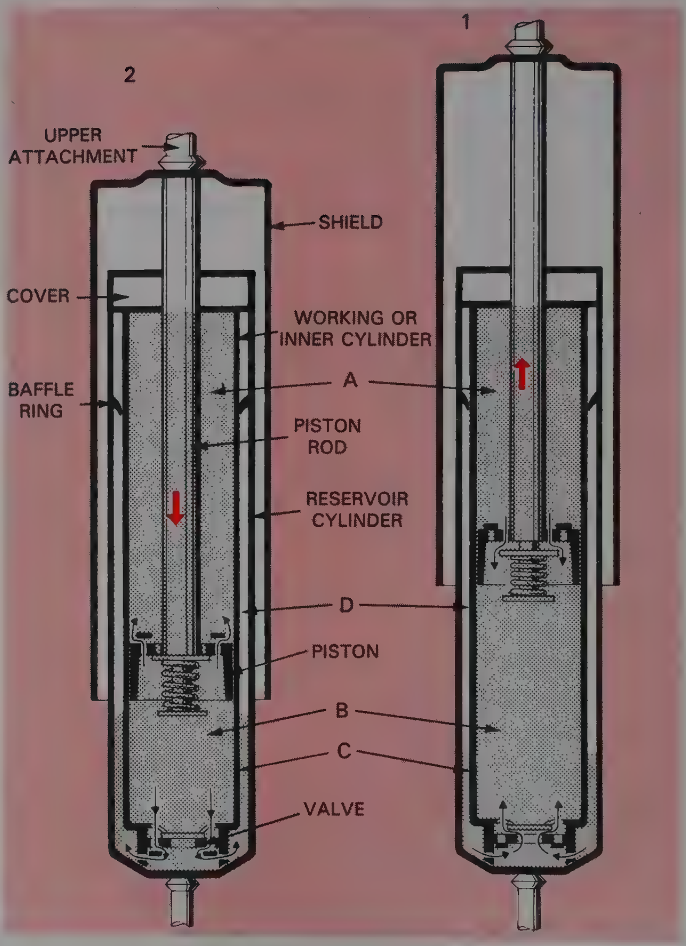


Fig. 33-104. Typical double-acting shock absorber action. (Volvo)

EXPELLING SHOCK ABSORBER AIR

Hold shock in upright position and extend fully to check for leaks. A small amount of fluid around the seal is not unusual and will not affect performance. Turn the shock upside down and compress it slowly. Do not extend the shock until it is upright again, Fig. 33-107. This sequence may be repeated several times to expel trapped air. If shock does not "firm up" (resist compression), it should be replaced.

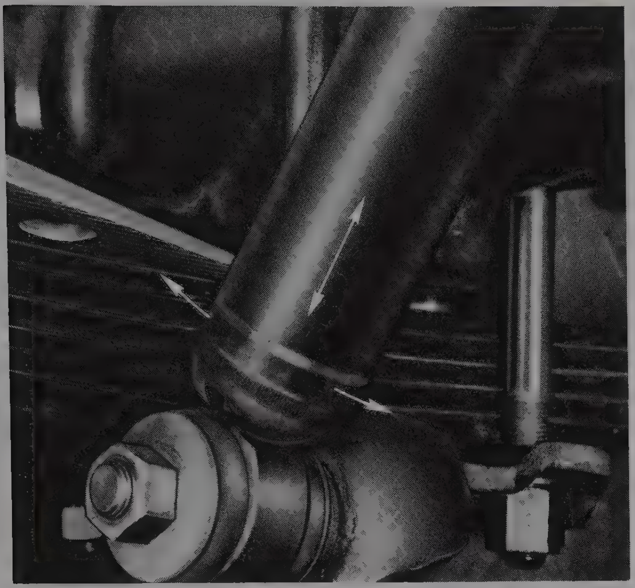


Fig. 33-105. Shake shock to check for worn rubber bushings and loose brackets or fasteners. (Dodge)

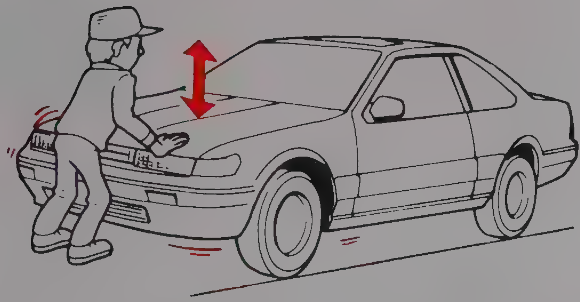


Fig. 33-106. To check the condition of shock absorbers, quickly bounce each corner of the car and release at the bottom of the downstroke. Shocks in good condition will allow one "free" bounce after the vehicle is released. This check can also be used with electronically controlled shocks. (Nissan)

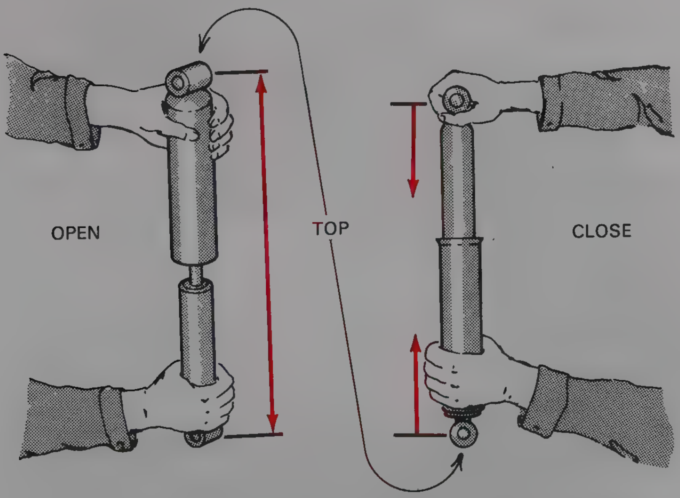


Fig. 33-107. Expelling air from a shock absorber. Always extend shock in the upright position. (Dodge)

BENCH TESTING SHOCK ABSORBER

Expel all air from the shock absorber piston compartment using the procedure outlined in the preceding section.

Grasp the shock in a vise. Place the anchor end in the jaws, not the tube portion. Shock must be RIGHT-SIDE UP and VERTICAL.

Work the shock through the full length of its travel several times. Resistance should be smooth and even in both directions. Work the shock back and forth sharply about mid-point in its travel. There should be no "free play" or time lag in the resistance.

As a further check, compare the overall action with a similar type of shock known to be in satisfactory condition.

Low pulling resistance, time lag when reversing, obvious physical damage or leakage will all necessitate shock replacement. See Fig. 33-108.

Although the service life of shocks depends on many variables such as original quality, road conditions, load, and driving habits, the useful life of the AVERAGE shock under AVERAGE conditions is around 15,000-20,000 miles (24 000-32 000 km). Although they may still function beyond this mileage, much of the damping action is lost.

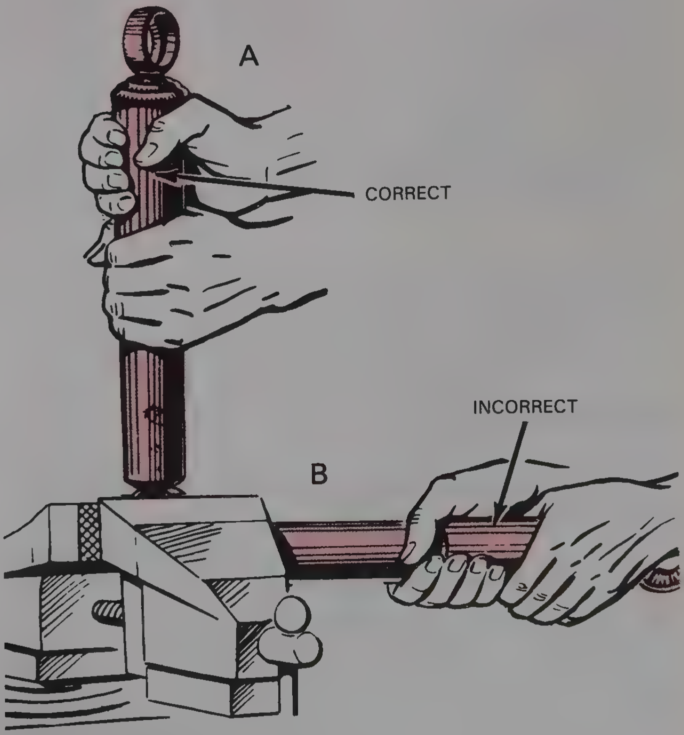


Fig. 33-108. Bench testing a shock absorber. A—Correct. B—Incorrect. (Thompson)

INSTALLING SHOCK ABSORBERS

Follow manufacturer's recommendations. Work air out of shocks before installing. Use new rubber bushings with new shocks. Install bushings and washers in correct order.

Make certain the heavy reinforcing plate (stone guard), where used, faces in the correct direction.

Tighten the shock mounting bolts with the vehicle at normal curb height (weight on wheels) to prevent placing the bushing under a strain. Do not overtighten fasteners.

Typical shock absorber mounting at the front of the car is pictured in Fig. 33-109. A strut damper (shock absorber) cutaway is shown in Fig. 33-110.

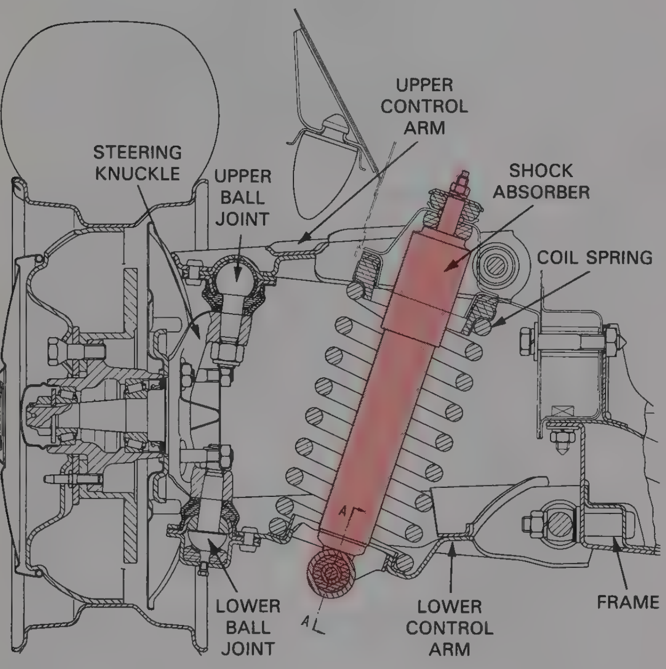

UPPER CONTROL ARM
STEERING KNUCKLE
UPPER BALL JOINT
SHOCK ABSORBER
COIL SPRING
A
A
LOWER BALL JOINT
LOWER CONTROL ARM
FRAME

Fig. 33-109. A popular method of mounting a shock absorber, as used on one type of independent front suspension. (Fiat)

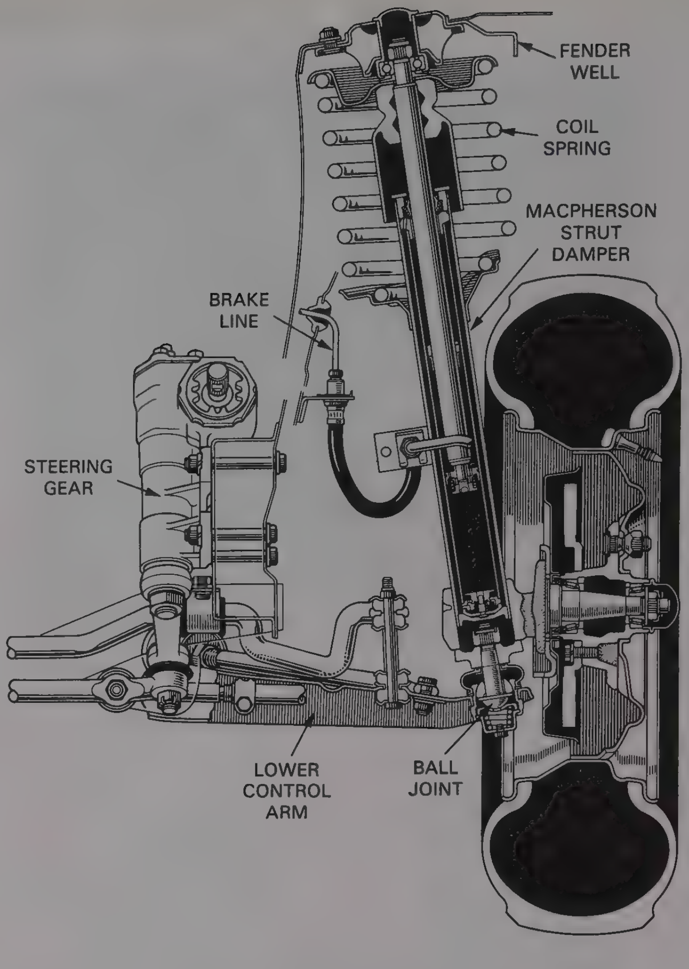

FENDER WELL
COIL SPRING
MACPHERSON STRUT DAMPER
BRAKE LINE
STEERING GEAR
LOWER CONTROL ARM
BALL JOINT

Fig. 33-110. One particular MacPherson strut damper (shock absorber) mounting arrangement. Note damper construction. (Toyota)

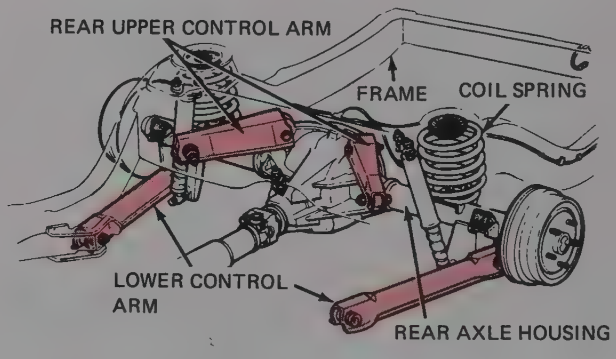

REAR UPPER CONTROL ARM
FRAME
COIL SPRING
LOWER CONTROL ARM
REAR AXLE HOUSING

Fig. 33-111. Rear axle housing is positioned by control arms (links) when coil springs are used. (Chevrolet)

REAR SUSPENSION

Most cars generally use either coil, leaf spring, or MacPherson strut suspension systems.

When coils are employed, control arms (also called control links or control struts) must be used to provide proper rear axle housing alignment.

Fig. 33-111 illustrates a typical control arm setup.

An exploded view of a coil spring rear suspension system is pictured in Fig. 33-112. Note how the upper control arm (link) is placed at an angle. These arms also function as the conventional track bar.

A coil spring rear suspension, as used with one particular front-wheel drive, is pictured in Fig. 33-113.

Fig. 33-114 shows a different form of rear suspension using leaf springs.

The independent rear suspension system in Fig. 33-115 uses a single, multiple-leaf spring, mounted in a transverse position. Another similar rear suspension has a single leaf spring made of Fiberglas. Coil springs are also common.

REPLACING REAR SUSPENSION CONTROL ARMS AND/OR BUSHINGS

When replacing rear suspension control arms or control arm bushings, it is important that the car be at

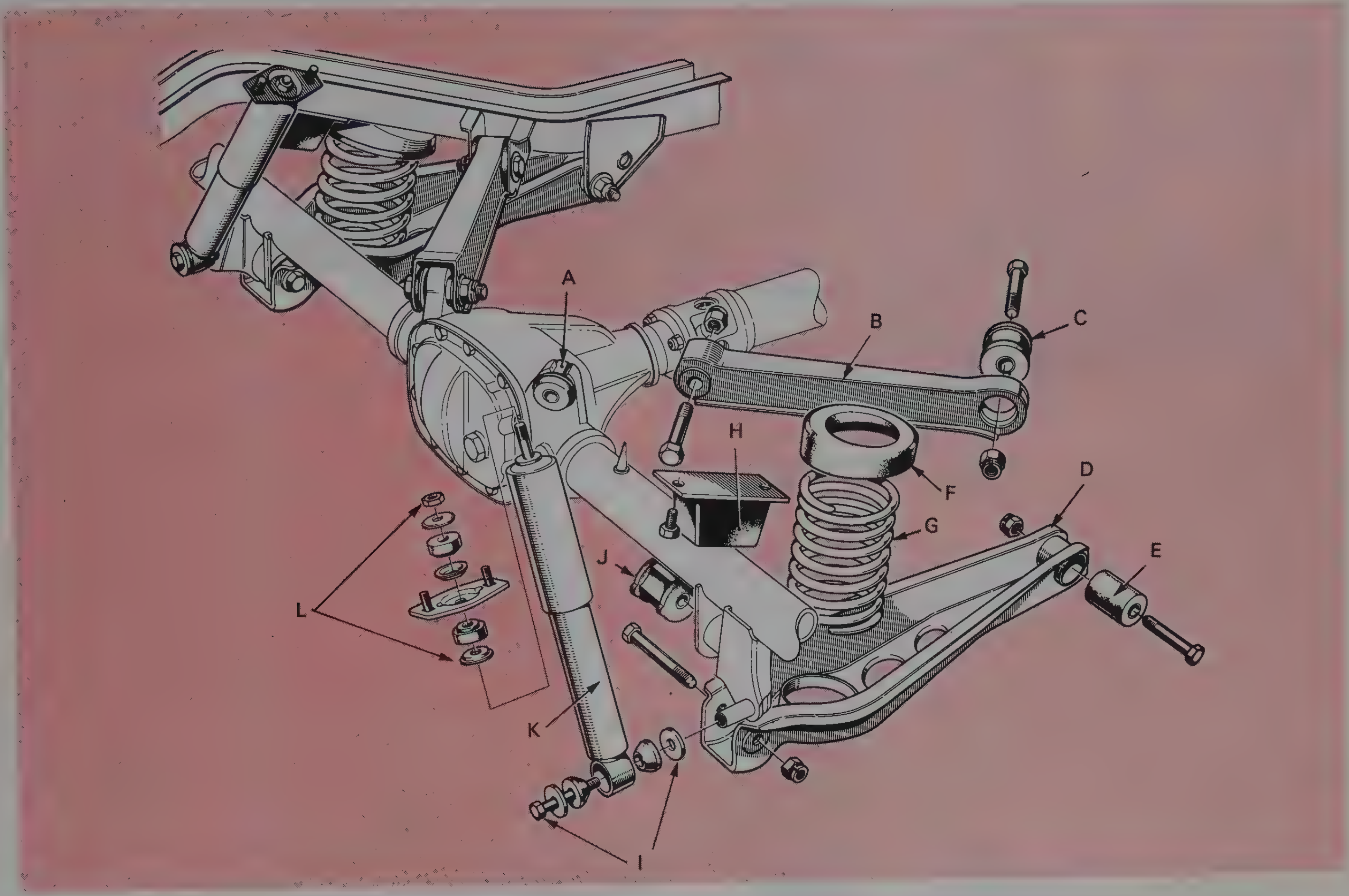


Fig. 33-112. Exploded view of a coil spring rear suspension. A—Upper link rear bushing. B—Upper link. C—Upper link front bushing. D—Lower link. E—Lower link front bushing. F—Coil spring insulator. G—Coil spring. H—Bump rubber. I—Lower mounting assembly. J—Lower link rear bushing. K—Shock absorber. L—Upper mounting assembly. (Plymouth)

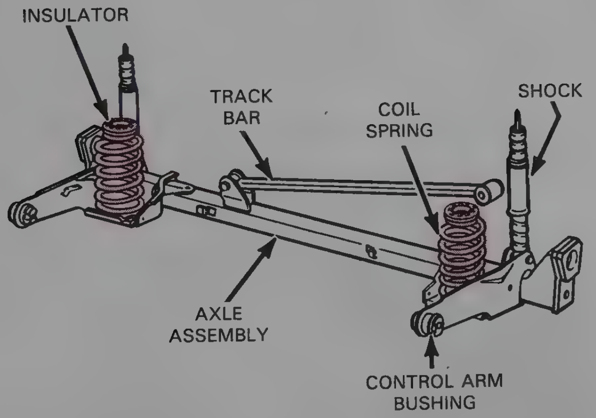


Fig. 33-113. Coil spring arrangement for one type of rear axle, as used with front-wheel drive. (Buick)

its normal standing height. The weight of vehicle must be on the rear wheels before tightening the control arm pivot bolts. This procedure applies to track bars as well.

By allowing the vehicle to return to normal standing height before tightening bolts, the rubber bushings will be at rest (no twisting strain on them) when in the normal position. This will allow flexing either way from normal without damage to the bushings.

Rubber bushings should be lubricated with RUBBER LUBE ONLY. NEVER LUBRICATE WITH ENGINE OIL, GREASE, OR KEROSENE.

Be very careful to place the control arms on the proper side, Fig. 33-116.

Check the drive angle of the differential pinion and adjust as needed. Drive angle may be changed by adjusting the length of the control arm or arms. Note in Fig. 33-117 that the upper control arm frame-to-rear axle housing distance may be varied through the use of an eccentric washer.

For complete details on differential pinion angle adjustment, see the chapter on rear axle service.

REAR SUSPENSION STANDING (CURB) HEIGHT

Rear standing height (height of vehicle at rest, no passengers, no luggage, full tank of gas, and with spare

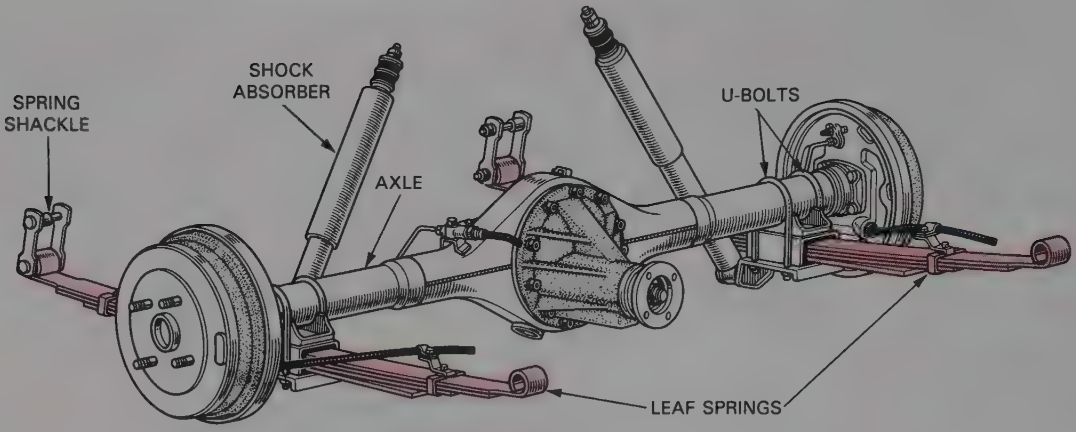

SHOCK ABSORBER
SPRING SHACKLE
AXLE
U-BOLTS
LEAF SPRINGS

Fig. 33-114. One type of leaf spring rear suspension. (Toyota)

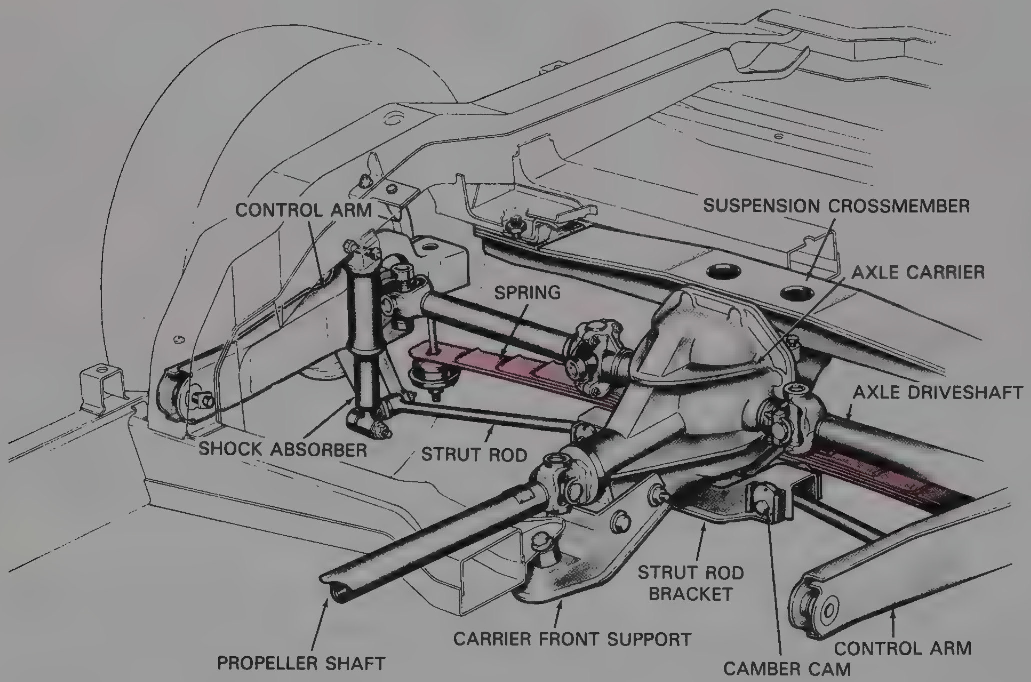

CONTROL ARM
SUSPENSION CROSSMEMBER
AXLE CARRIER
SPRING
AXLE DRIVESHAFT
SHOCK ABSORBER
STRUT ROD
STRUT ROD BRACKET
CARRIER FRONT SUPPORT
PROPELLER SHAFT
CAMBER CAM
CONTROL ARM

Fig. 33-115. One transversely mounted multiple-leaf spring serves this independent rear suspension. (Corvette)

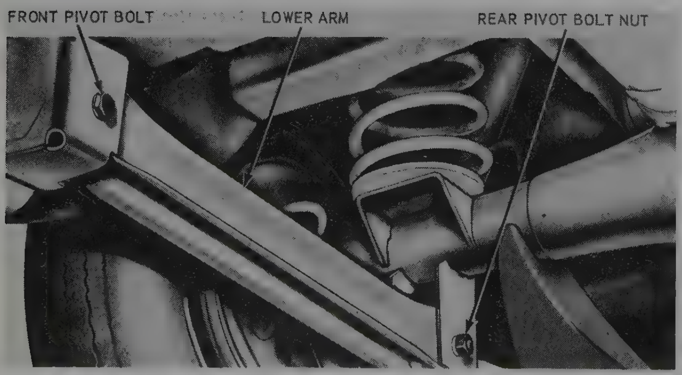

FRONT PIVOT BOLT
LOWER ARM
REAR PIVOT BOLT NUT

Fig. 33-116. Car should be at normal standing height before tightening bushing pivot bolts. (Ford)

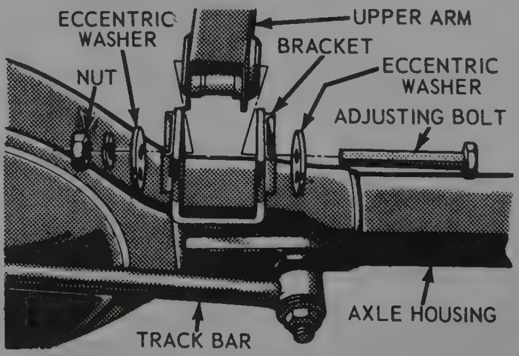

ECCENTRIC WASHER
UPPER ARM
BRACKET
NUT
ECCENTRIC WASHER
ADJUSTING BOLT
AXLE HOUSING
TRACK BAR

Fig. 33-117. This rear axle housing may be tilted to adjust pinion drive angle by varying upper control arm length. Length may be altered by eccentric washer setup.

tire in trunk) can be altered by weak, broken, or extra stiff springs.

Standing height is often determined by measuring from the top of the rear axle housing to a given point on the frame. See Fig. 33-118.

Always check rear standing or curb height before aligning front end or when checking for cause of bottoming, stiff ride, or lean.

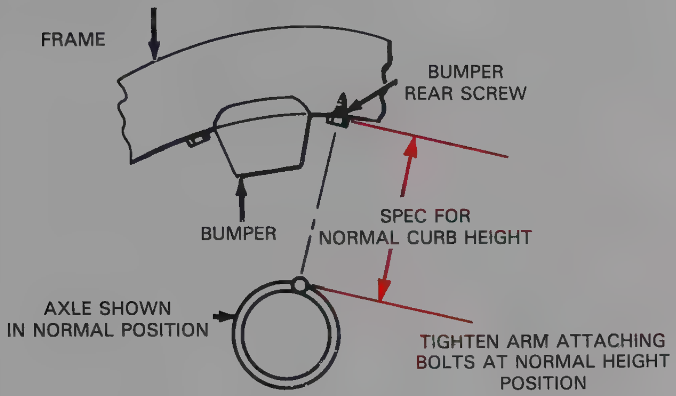

FRAME
BUMPER REAR SCREW
BUMPER
SPEC FOR NORMAL CURB HEIGHT
AXLE SHOWN IN NORMAL POSITION
TIGHTEN ARM ATTACHING BOLTS AT NORMAL HEIGHT POSITION

Fig. 33-118. Measuring standing height. (Ford)

LEAF SPRINGS

Some leaf spring bushings are best removed and installed by using a suitable puller as pictured in Fig. 33-119.

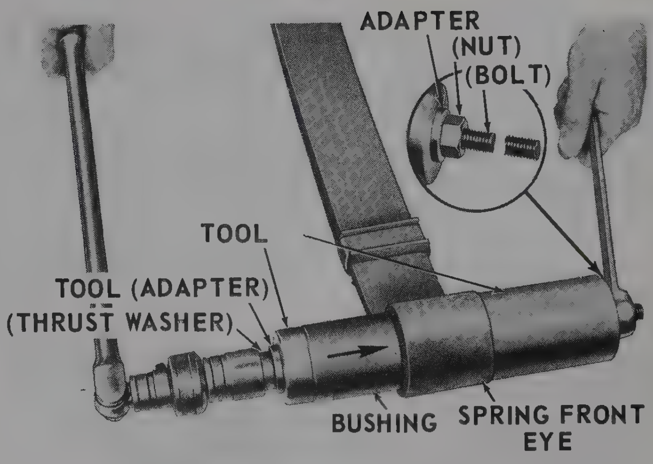

ADAPTER
(NUT)
(BOLT)
TOOL
TOOL (ADAPTER)
(THRUST WASHER)
BUSHING
SPRING FRONT EYE

Fig. 33-119. Installing new leaf spring bushing.

Following removal of old bushing, clean spring eye thoroughly. Coat with a suitable lubricant before pulling new bushing into position. Allow weight of vehicle to rest on bushings before torquing shackle bolts.

Replace any broken spring leaves. Use inserts between spring leaves (where required). Spring center bolt must be tight. Torque spring U-bolts, Fig. 33-114.

All spring rebound clips must be in place. Be careful when removing or replacing a Fiberglas spring. Nicks, chips, or other damage from rough handling can lead to spring failure.

AUTOMATIC LEVEL CONTROL

Some vehicles are equipped with automatic level control. This system is used to maintain a nearly constant

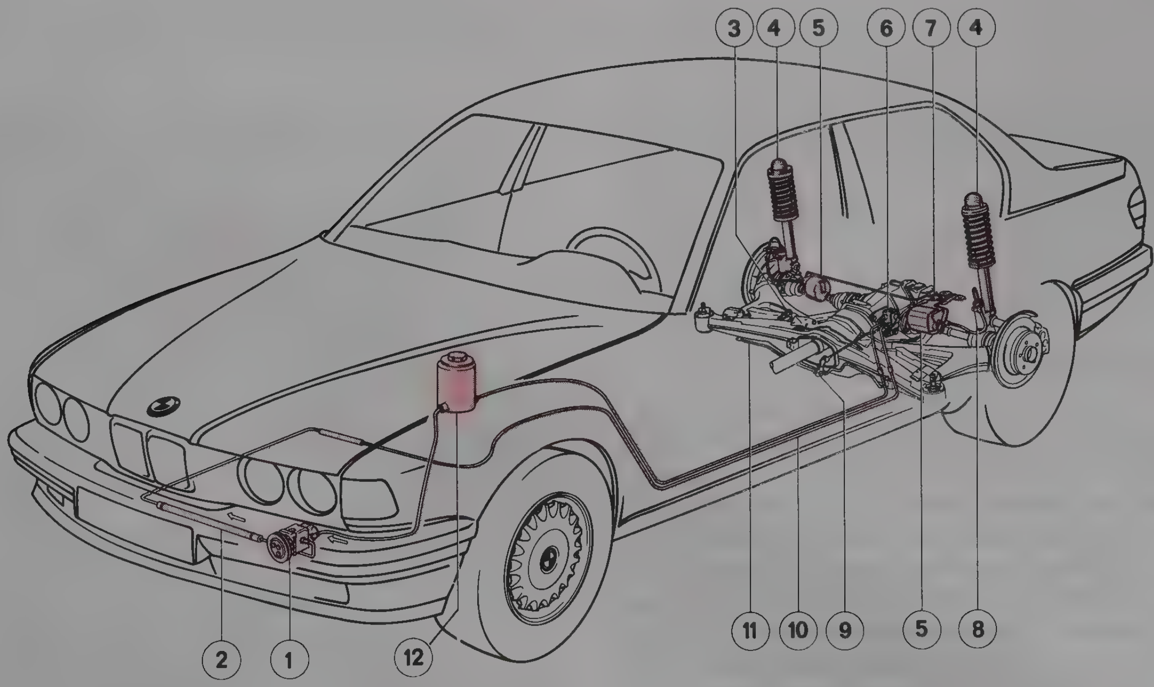

3
4
5
6
7
4
2
1
12
11
10
9
5
8

Fig. 33-120. One type of load leveling system that uses a hydraulic power steering pump. Note the wheel camber switch, which triggers an instrument cluster lamp when overloading of the vehicle produces excessive wheel camber. 1—Pump. 2—Expansion hose. 3—Wheel camber warning switch. 4—Spring strut. 5—Pressure reservoir. 6—Regulating valve. 7—Branch. 8—LAD (load absorbing dependent). 9—Regulating linkage mount with regulating rod. 10—Feed and return lines. 11—Stabilizer. 12—Fluid reservoir. (BMW)

curb height at the rear of the car, as measured from the frame or bumper to the ground. Most systems will level the vehicle with additional weight of up to approximately 500 pounds (227 kg).

A basic system will generally include an air compressor (vacuum or electrically operated air pump), air tank (reservoir), pressure regulator, height control valve, special shock absorbers, connecting wire, tubing, hose, and an air dryer.

An automatic level control system using an oil pump is pictured in Fig. 33-120.

One particular level system that uses an electrically driven vacuum pump is shown in Fig. 33-121.

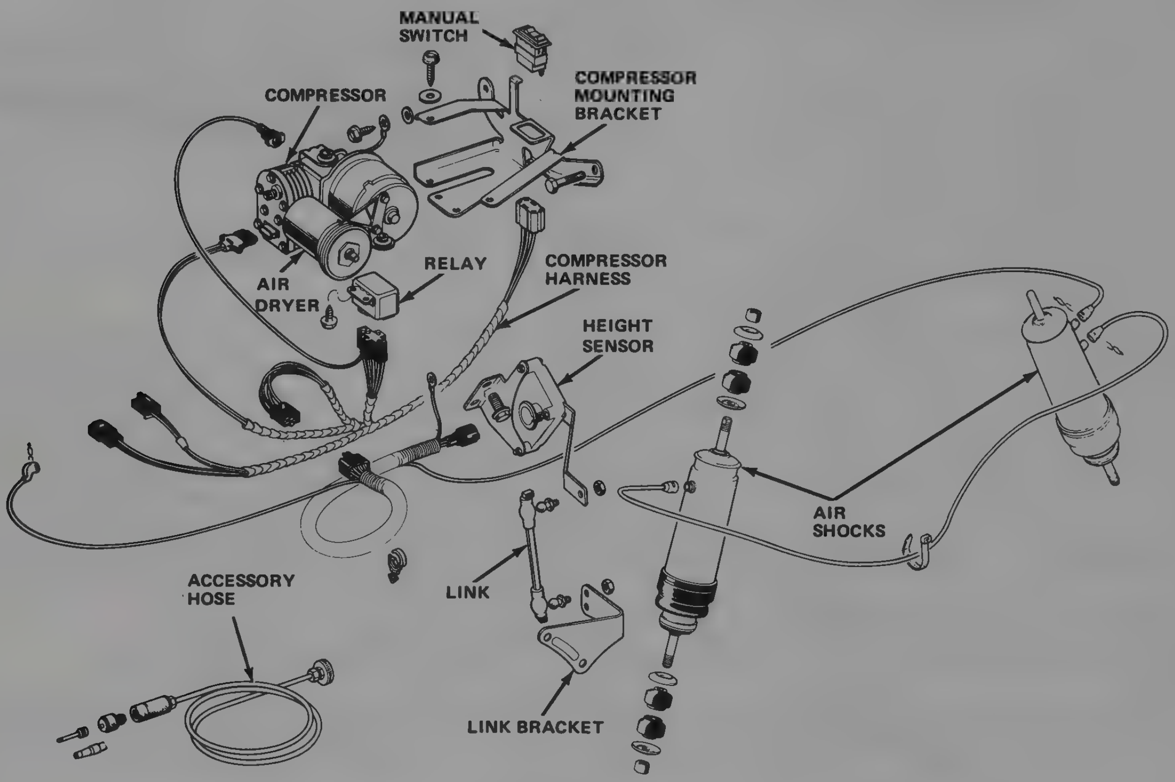

MANUAL SWITCH
COMPRESSOR
COMPRESSOR MOUNTING BRACKET
RELAY
AIR DRYER
COMPRESSOR HARNESS
HEIGHT SENSOR
AIR SHOCKS
ACCESSORY HOSE
LINK
LINK BRACKET

Fig. 33-121. An automatic level system using an electrically operated compressor. (AMC)

HEIGHT CONTROL VALVE

A height control valve (also called sensor) is attached to the vehicle frame. The unit is connected to a suspension arm or the rear axle housing. The valve senses any distance changes between the frame and suspension by an overtravel lever (actuating arm).

As the distance changes, the overtravel lever will cause the control valve to admit more air to the shocks or exhaust some, either mechanically (by moving valves) or electrically by starting the compressor. Fig. 33-122 illustrates an electric height control unit with linkage.

AIR SHOCK ABSORBERS

The automatic level control system generally uses two air-operated (hydraulically damped) shocks or struts.

The shocks operate in the conventional manner, with the added benefit of being able to extend or decrease

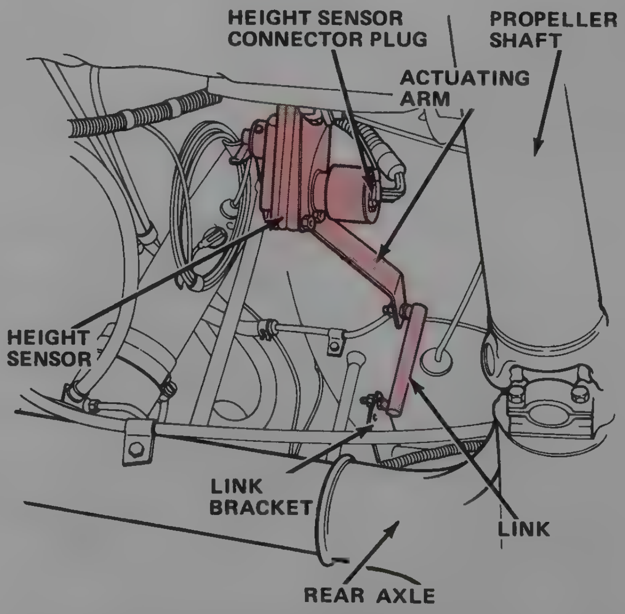

HEIGHT SENSOR CONNECTOR PLUG
PROPELLER SHAFT
ACTUATING ARM
HEIGHT SENSOR
LINK BRACKET
LINK
REAR AXLE

Fig. 33-122. An electric height sensor, actuating arm and related parts. (AMC)

their operating range length with an air chamber, rubber boot, and fittings. A cutaway of an air-hydraulic strut is illustrated in Fig. 33-123.

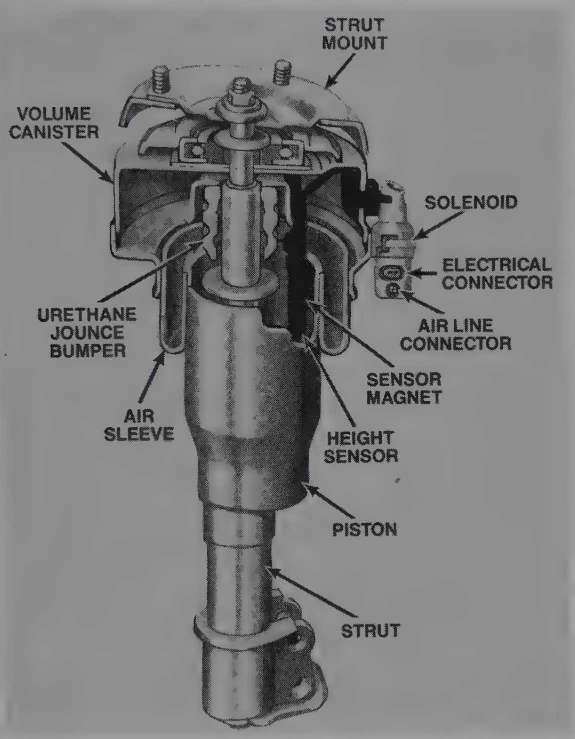


Fig. 33-123. Cutaway view of an electronically controlled air-hydraulic strut. (Chrysler)

AUTOMATIC LEVEL CONTROL SERVICE — SYSTEM OPERATION CHECK

The following is a general service procedure to be used BEFORE other checks are made.

Determine the vehicle recommended curb height (also called trim height). Start the engine and run it for a few seconds (15-30 is usually sufficient). Place two people (or equivalent weight) in the rear seat.

There should be a delay of 8-14 seconds (ignition on), with most systems, before the vehicle begins to raise. The height obtained when compressor shuts off should be within 3/4 in. (19.1 mm) of the specified curb height at the beginning of test.

Remove people (or equivalent weight) from vehicle. There should be an 8-14 second delay before the car begins to lower.

If the level control system fails this preliminary test, use vehicle manufacturer's service manual and follow ALL repair steps exactly.

Areas of inspection should include the following:

1. Compressor.
2. Height sensor.
3. Tubing and hose and connections.
4. Air shocks.
5. Electrical connections and wire.
6. Electric relays.
7. Fuses.
8. Pressure regulator.
9. Exhaust solenoid.

ELECTRONICALLY CONTROLLED SHOCK ABSORBERS

Some vehicles use electrically controlled shock absorbers at two or four wheels. This "ACTIVE" type of suspension provides a change in vehicle handling in relation to speed, braking, and road conditions. Follow all manufacturer's recommendations for service and repair. See Fig. 33-124. For more information on electronic (computerized) suspension systems, see Chapter 24.

SUMMARY

The steering wheel, steering shaft, steering gear (conventional and rack and pinion), pitman arm, linkage, steering arms and spindle body make up the steering system components.

Check lubricant level in manual steering gear periodically. Use recommended lubricant when adding.

The most common type of steering gear is the recirculating ball worm and nut.

Manual steering gears usually have two adjustments: worm bearing preload and over-center adjustment. Make worm bearing preload adjustment first.

Use care when turning the steering gear to extreme left or right when the pitman arm is disconnected. Use an accurate torque wrench or spring scale to check and adjust steering gear. Pitman arm must be disconnected.

All steering system work is critical to the safe operation of the vehicle. Do it carefully and well!

There are two basic types of power steering systems: the rack and pinion and the self-contained (integral) type.

The in-line power steering gear has three basic adjustments: thrust bearing preload, worm to rack-piston preload, and pitman shaft over-center preload.

When repairing power steering gears, use care to keep dirt away from parts. Avoid denting or nicking parts. Do not force parts together. Use new seals and gaskets. Lubricate parts before assembly.

Steering gear must be properly aligned with steering shaft.

Adjust steering wheel spoke position by turning tie rod adjusting sleeves. Steering wheel hub and shaft marks must be aligned. When installing a steering wheel, align marks. Torque retaining nut. Stake or cement to prevent loosening.

Power steering pumps can be of the vane, slipper, roller, or gear types.

Steering pumps are generally belt driven. However, one design incorporates the pump as an integral part of the front engine plate. It drives the pump directly from the crankshaft.

When overhauling power steering pumps, use care to avoid nicking parts. Clean all parts thoroughly. Use new seals and gaskets. Lubricate parts before assembly.

Replace soft, cracked, or abraided power steering hose. Use quality replacement hose. Torque all connections. Bleed air from hose, gear, and pump by turning steering wheel from one side to the other several times (engine running).

The steering system should have a thorough inspection at regular intervals. Inspection should cover linkage connections, tie rod adjuster sleeve clamps, all system fasteners, steering arms, pitman arm, steering gear, power steering pump lubricant level, power steering pump belts, power steering hose, and pump fluid cooler (where used). Road test vehicle for proper steering.

Before conducting a power steering pressure test, check belt tension and reservoir fluid level. Use a 0-2000 psi (0-13 800 kPa) gauge. Never close the pressure test shutoff valve or hold the steering wheel hard against the stops for a period exceeding five seconds.

When adjusting pump belt tension, pry on a heavy section (not filler pipe or reservoir) of pump or use the notch for a wrench in mounting bracket.

Tension a new belt slightly tighter than a used belt to allow for initial belt stretch.

When adjusting, removing, or installing belts, remove battery ground strap.

When removing or installing the pitman arm, never hammer on the end of the pitman shaft or the end of puller. When installing pitman arm on shaft, align correctly. Torque pitman retaining nut and stake to prevent loosening.

Tie rod adjuster sleeves must be installed with an equal number of threads engaged on each end. Position sleeve clamps over threaded area and turn to specified angle.

Loose idler arm bushings must be replaced.

Front suspension systems use either coil, leaf, or torsion bar springs.

Ball joints are used to allow up and down as well as swivel action of the spindle body.

One ball joint is loaded (main load-carrying joint) while the other is nonloaded (follower joint). Ball joint may be tension or compression loaded.

To check ball joint wear, the joints must be unloaded (pressure removed). When coil spring is between lower arm and frame, unload joint by placing jack beneath lower arm. When coil spring is between upper suspension arm and body, place jack beneath frame. In some cases, a wedge must be placed between the underside of the upper arm and the frame.

Check ball joint wear by measuring either axial (up and down) movement or side to side movement of the tire.

The use of a suitable puller eases ball joint removal. Rapping the spindle also helps. Always use great care, when removing ball joints, to prevent the coil spring from slamming the suspension arm downward. Use a jack.

When bolting new ball joints to suspension arms, use special bolts supplied for the purpose. Lubricate joint.

Some joints are welded to the arm. Both the arm and joint are serviced as an assembly. Both parts replaced.

Some front suspension (conventional and MacPherson strut) coil springs must be compressed for removal or installation. Others may be unloaded by slowly lowering the lower suspension arm.

Watch out. Loaded coil springs have tremendous force. Use a jack to lower the suspension arm.

Use spring insulators where required. Position spring end as specified. Do not nick or dent springs. Spring sagging (broken or weak) may be detected by measuring car standing height.

Remove torsion bar by unloading front suspension arms and then backing off bar tension rear adjuster. Bar must be free of nicks and burrs. Lubricate both ends. Never heat a torsion bar or bar anchors. Set car standing height by turning torsion bar adjusting bolt.

When removing suspension arms, note number and location of camber and caster shims (where used). If a slotted inner shaft is used, center punch frame and shaft to assist in regaining preliminary camber and caster adjustment.

When pressing suspension arm bushings out or in, use a stiffener tool to prevent distorting the arms.

Shock absorbers and strut dampers must function well to provide safe handling and a comfortable ride. Check shock operation by bouncing vehicle or by bench testing shocks.

The most commonly used shock is the telescopic, direct, double-acting type. Some shocks are adjustable while others are not.

When bench testing shocks, work all air from the cylinder. Hold shock, right-side up, in a vertical position. Action must be smooth with no play when direction of motion is changed.

Install shocks right-side up. If a stone shield is used, place in correct direction. Do not overtighten shock bushing fasteners.

Rear suspension systems commonly use either leaf or coil springs.

Replace sagged rear coil springs. Replace weak or broken leaf springs.

Place weight of vehicle on spring shackle bushings before tightening bushing fasteners.

When installing rear axle control arms, check pinion shaft drive angle. Have car at normal standing height before tightening control arm bushing bolts. Use rubber lubricant ONLY on rubber bushings.

Check rear standing height. Car must be at curb weight when checking.

Some vehicles are equipped with automatic level control. This system keeps curb height correct when car has additional weight or passengers. The system uses an air compressor, valves, tubing and hose, height sensor, and air shocks.

Some cars employ air-operated, electrically controlled shock absorbers (ACTIVE SUSPENSION) at all wheels.

PROBLEM DIAGNOSIS: MANUAL AND POWER STEERING SYSTEMS

PROBLEM: HARD STEERING AND POOR RECOVERY FOLLOWING TURNS

Possible Cause	Correction
1. Tire pressure low.	1. Inflate to correct pressure.
2. Power steering pump defective.	2. Repair or replace pump.
3. Power steering pump fluid level low.	3. Add fluid to reservoir.
4. Manual steering gear lubricant level low.	4. Add lubricant.
5. Incorrect front wheel alignment.	5. Align front wheels.
6. Ball joints dry.	6. Lubricate ball joints.
7. Steering linkage sockets dry.	7. Lubricate linkage.
8. Linkage binding.	8. Relieve binding.
9. Damaged suspension arms.	9. Replace arms.
10. Steering gear adjusted too tight.	10. Adjust gear correctly.
11. Steering shaft bushing dry.	11. Lubricate bushings.
12. Steering shaft bushing or coupling binding.	12. Align shaft or coupling.
13. Excessive caster.	13. Adjust caster.
14. Sagged front spring.	14. Replace spring.
15. Bent spindle body.	15. Replace spindle.
16. Steering wheel rubbing steering column jacket.	16. Adjust jacket.
17. Steering gear misaligned.	17. Align gear.
18. Sticky valve spool.	18. Clean or replace.
19. Steering pump belt loose.	19. Adjust belt tension.
20. Power steering hose kinked or clogged.	20. Replace hose.
21. Different size front tires.	21. Install correct size tires on both sides.
22. Malfunctioning steering gear pressure port poppet valve.	22. Repair or replace.
23. Rack and pinion adjusted incorrectly.	23. Adjust to specs.
24. High internal leakage of rack and pinion assembly.	24. Repair leak(s).
25. Rack and pinion mountings loose, causing binding.	25. Tighten mountings to specifications.
26. Defective steering stabilizer.	26. Replace stabilizer.

PROBLEM: CAR PULLS TO ONE SIDE

Possible Cause	Correction
1. Uneven tire pressure.	1. Equalize pressure.
2. Brakes dragging.	2. Adjust brakes.
3. Improper front end alignment.	3. Align front end.
4. Wheel bearings improperly adjusted.	4. Adjust bearings.
5. Damaged or worn valve shaft assembly.	5. Replace assembly.
6. Tire sizes not uniform.	6. Install all tires of same size.
7. Broken or sagged spring.	7. Replace spring.
8. Rear axle housing misaligned.	8. Align rear housing.
9. Bent spindle.	9. Replace spindle.
10. Frame sprung.	10. Straighten frame.
11. Radial tire problems.	11. Switch front tires. If car now pulls in other direction, tire(s) are defective. Replace.

PROBLEM: CAR WANDERS FROM SIDE TO SIDE

Possible Cause	Correction
1. Weak shock absorber.	1. Replace shocks.
2. Loose steering gear.	2. Torque mounting fasteners.
3. Loose rack and pinion mountings.	3. Tighten to specs.
4. Ball joints and steering linkage need lubrication.	4. Lubricate.
5. Steering gear not on high point.	5. Adjust.
6. Broken stabilizer bar or missing link.	6. Replace stabilizer or link.
7. Rack and pinion improperly adjusted.	7. Adjust to specifications.
8. Tie rod end loose.	8. Tighten. Replace if worn.

PROBLEM: SUDDEN INCREASE IN STEERING WHEEL RESISTANCE WHEN TURNING WHEEL FAST IN EITHER DIRECTION

Possible Cause	Correction
1. Pump belt slipping.	1. Adjust belt tension.
2. Internal leakage in gear.	2. Overhaul gear.
3. Fluid level low in pump.	3. Add fluid.
4. Engine idle too slow.	4. Adjust idle.
5. Air in system.	5. Bleed system.
6. Low tire air pressure.	6. Inflate to recommended level.
7. Insufficient pump pressure.	7. Test. Repair or replace as required.
8. High internal leakage in rack and pinion.	8. Repair leak(s).
9. Defective steering stabilizer.	9. Replace stabilizer.

PROBLEM: STEERING WHEEL ACTION JERKY DURING PARKING

Possible Cause	Correction
1. Loose pump belt.	1. Adjust belt tension.
2. Oily pump belt.	2. Replace belt. Clean pulleys. Repair source of leak.
3. Defective flow control valve.	3. Replace valve.
4. Insufficient pump pressure.	4. Test and repair.

PROBLEM: NO TURNING EFFORT REQUIRED TO TURN WHEEL

Possible Cause	Correction
1. Steering gear torsion bar broken.	1. Replace spool valve and shaft assembly.
2. Broken tilt column U-joint.	2. Replace joint.
3. Steering wheel hub-to-shaft key missing. Splines stripped. Loose nut.	3. Replace key, shaft, or wheel. Tighten nut to specifications.

PROBLEM: EXCESSIVE WHEEL KICKBACK AND PLAY

Possible Cause	Correction
1. Steering linkage worn.	1. Replace ball sockets.
2. Air in system.	2. Bleed and add fluid if needed.
3. Front wheel bearings improperly adjusted.	3. Adjust front wheel bearings.
4. Gear over-center adjustment loose.	4. Make correct over-center adjustment.
5. Worm not preloaded.	5. Preload worm gear.
6. No worm to rack-piston preload.	6. Install larger set of balls.
7. Loose pitman arm.	7. Torque nut.
8. Loose steering gear.	8. Tighten mounting fasteners.
9. Steering arms loose on spindle body.	9. Tighten arm fasteners.
10. Loose ball joints.	10. Replace ball joints.
11. Defective rotary valve.	11. Replace valve.
12. Worn steering shaft universal joint.	12. Replace joint and/or shaft.
13. Extra large tires.	13. Advise owner. Install a steering stabilizer or go to a larger stabilizer.
14. Defective steering stabilizer.	14. Replace stabilizer.

PROBLEM: NO POWER ASSIST IN ONE DIRECTION

Possible Cause	Correction
1. Defective steering gear.	1. Overhaul gear as needed.

PROBLEM: STEERING PUMP PRESSURE LOW

Possible Cause	Correction
1. Pump belt loose.	1. Adjust belt.
2. Belt oily.	2. Clean pulleys. Replace belt. Correct source of leak.
3. Pump parts worn.	3. Overhaul pump.
4. Relief valve springs defective. Valve stuck open.	4. Repair or replace as needed.
5. Low fluid level in reservoir.	5. Add fluid.
6. Air in system.	6. Correct source of leak. Bleed system.

7. Defective hose.	7. Replace hose.
8. Flow control valve stuck open.	8. Clean.
9. Pressure plate not seated against cam ring.	9. Repair.
10. Scored pressure plate, thrust plate, or rotor.	10. Replace damaged parts and flush system.
11. Vane(s) incorrectly installed.	11. Install correctly.
12. Vanes sticking in rotor.	12. Free vanes. Clean thoroughly.
13. Worn or damaged O-rings.	13. Replace O-rings.

PROBLEM: STEERING PUMP NOISE

Possible Cause	Correction
1. Air in system.	1. Bleed. Correct leak.
2. Loose pump pulley.	2. Tighten pulley.
3. Loose belt.	3. Tension belt correctly.
4. Glazed belt.	4. Replace belt.
5. Hoses touching splash shield.	5. Route hose to prevent contact with thin sheet metal that acts as a sounding board.
6. Low fluid level.	6. Add fluid.
7. Clogged or kinked hose.	7. Replace hose.
8. Scored pressure plate.	8. Polish. Replace if badly scored.
9. Scored rotor.	9. Polish. Replace if badly scored.
10. Vanes installed wrong.	10. Install correctly.
11. Vanes sticking in rotor.	11. Clean.
12. Defective flow control valve.	12. Replace valve.
13. Loose pump.	13. Tighten pump mounting fasteners.
14. Reservoir vent plugged.	14. Clean vent.
15. Dirty fluid.	15. Drain. Flush. Refill.
16. Pump bearing worn.	16. Overhaul as needed.
17. Chirp type noise.	17. Loose belt. Tighten.
18. Whine or growl.	18. Low fluid. Fill to proper level.

PROBLEM: STEERING GEAR DULL RATTLE OR CHUCKLE

Possible Cause	Correction
1. Gear loose on frame.	1. Tighten gear mounting fasteners.
2. Loose over-center adjustment.	2. Make correct over-center adjustment.
3. No worm shaft preload.	3. Adjust preload.
4. Insufficient or improper lubricant (manual gear).	4. Fill with specified lubricant.

PROBLEM: HISSING SOUND IN GEAR

Possible Cause	Correction
1. Normal sound when turning wheel when car is standing still or when holding wheel against stops.	1. None.
2. Gear loose.	2. Tighten mounting fasteners.
3. Noisy valve.	3. Replace valve.
4. Intermediate shaft rubber plug missing.	4. Replace plug.

PROBLEM: TIRE SQUEAL ON TURNS

Possible Cause	Correction
1. Excessive speed.	1. Caution driver.
2. Low air pressure.	2. Inflate to correct pressure.
3. Faulty wheel alignment.	3. Align wheels.
4. Excessive load.	4. Caution driver.
5. Rack and pinion mountings loose.	5. Tighten mountings to specifications.

PROBLEM: EXTERNAL FLUID LEAKS

Possible Cause	Correction
1. Defective hose.	1. Replace hose.
2. Loose hose connections.	2. Tighten to proper torque.
3. Cracked hose connections.	3. Replace.
4. Pitman shaft seal in gear defective.	4. Replace seal. Check bearing for excessive wear.

5. Gear housing end cover O-ring seal.	5. Replace seal.
6. Gear torsion bar seal.	6. Replace valve and shaft assembly.
7. Adjuster plug seals.	7. Replace seals.
8. Side cover gasket.	8. Replace gasket.
9. Pump too full.	9. Reduce fluid level.
10. Pump shaft seal defective.	10. Replace shaft seal.
11. Scored shaft in pump.	11. Replace shaft.
12. Oil leaking out of reservoir from air contamination.	12. Correct source of air leak.
13. Pump assembly fasteners loose.	13. Torque fasteners.
14. Leaking power cylinder (linkage type).	14. Overhaul as needed.
15. Rack and pinion housing cracked.	15. Replace housing.
16. Extreme cam ring wear.	16. Replace parts. Flush system.
17. Scored pressure plate, rotor, or thrust plate.	17. Replace parts. Flush system.
18. Vanes incorrectly installed.	18. Install properly.
19. Reservoir cracked.	19. Replace.
20. Pump reservoir cap leaking.	20. Repair or replace cap.
21. Defective rack and pinion stub shaft seal.	21. Replace seal.
22. Defective rack and pinion rotary valve.	22. Replace valve.
23. Pinion shaft seal leaking.	23. Replace seal.
24. Rack and pinion bulkhead seal defective.	24. Replace seal.

KNOW THESE TERMS

Pitman arm, E.P. lubricant, Sector shaft, Sector gear, Worm bearing, Worm shaft, Pitman shaft, Ball nut, Preload, Over-center adjustment. Rotary valve, Rack-piston, Slipper pump, Vane pump, Parallelogram linkage, Idler arm, Tie rod, MacPherson strut, Torsion bar, Control arm, Ball joint, Tension loading, Compression loading, Steering knuckle, Full rebound, Suspension height, Spring oscillation, Spring rebound, Straddle mounted, Transverse mounted, Curb height.

QUIZ - Chapter 33

1. List six of the major steering system components.
2. When checking manual steering gear lubricant level, __________ __________ the filler plug and surrounding area before __________ __________.
3. The type of steering gear in common use is the:
    a. Worm and sector.
    b. Recirculating ball worm and nut.
    c. Worm and taper pin.
    d. Rack and pinion.
4. The typical manual steering gear has two basic adjustments __________ __________ preload and __________ __________.
5. Which of the two adjustments in Question 4 is done first?
6. Steering gear ball guides can be damaged by turning the steering wheel sharply against the stops when the pitman arm is disconnected. True or False?
7. Steering gear adjustments are usually checked by using a __________ wrench or a __________ __________.
8. Power steering systems are of two general types. Name them.
9. Explain the operation of a power steering system during a turn.
10. A power steering gear can have three basic adjustments: A—__________ __________ preload. B—Pitman shaft __________ preload. C—__________ to __________ preload.
11. When overhauling any hydraulic unit, one of the most important rules is:
    a. Speed.
    b. Painting the exterior.
    c. Cleanliness.
    d. Use of labor saving tools.
12. The steering gear must be correctly aligned with the steering shaft. True or False?
13. Adjust steering wheel spoke position by removing wheel and relocating on steering shaft. True or False?
14. To prevent the steering wheel retaining nut from loosening, either __________ the nut or use __________ on the exposed threads.
15. Power steering pumps can be of the __________, __________, or __________ type.
16. A squealing sound when turning the steering wheel against the stops usually indicates a loose power steering __________.
17. When checking power steering fluid level in the pump, the fluid must be at __________ __________.
18. List five important power steering system checks.
19. A faulty power steering pump is readily detected by conducting a __________ test.
20. When conducting the test in Question 19, never leave the shutoff valve closed for longer than __________ __________.
21. Power steering belt adjustment is best checked with a __________ __________.
22. Pry on the reservoir when setting power steering pump belt adjustment. True or False?
23. When removing a pitman arm, never pound on the __________ of the pitman shaft.
24. Tie rod adjuster sleeve clamps can be tightened in any handy position. True or False?
25. Front suspension ball joints can be __________

or __________ loaded.

26. One of the ball joints is the main load-carrying joint while the other acts as a follower or guide. True or False?
27. Ball joint wear is best detected by measuring either wheel and tire __________ movement or tire __________ movement.
28. Before checking ball joint wear, the joint must be __________.
29. Allowable wear tolerances for ball joints are about the same for all cars. True or False?
30. When placing a jack under the lower suspension arm to lower the arm following ball joint stud removal, place the jack __________ to the length of the lower arm.
31. Lowering the lower arm to release coil spring tension can be dangerous if done incorrectly. True or False?
32. Special high strength fasteners are required when bolting ball joints to the suspension arms. True or False?
33. A spring compressor is always needed to remove front suspension system coil springs. True or False?
34. Vehicle standing height (car equipped with torsion bars) can be changed by adjusting torsion bar anchor tension. True or False?
35. When removing or installing a torsion bar, avoid __________ or __________ the surface of the bar.
36. To avoid distorting the suspension arm when pressing out bushings, use a:
    a. Stiffener plate.
    b. Vise.
    c. New bushing.
    d. Small hammer.
37. Worn front suspension arm bushings can change front alignment angles. Of the various front wheel angles discussed in Chapter 32, name four you feel could be altered.
38. What important rear axle angle can be adjusted by altering the length of rear control arms.
39. Test shock absorbers in a __________ position.
40. All shock absorbers are adjustable. True or False?
41. Bouncing the car is one way to test shock general condition. After releasing the car, how many bounces (oscillations) should the car make before stopping, if the shocks are good?
42. Rear suspension systems generally use __________ or __________ springs.
43. The rack, in a rack and pinion steering gear, operates back and forth in what direction in relation to the car?
    a. Transverse.
    b. Longitudinal.
    c. Vertical.
    d. Rotary.
44. A __________ covers each inner socket assembly on a rack and pinion setup.
45. All MacPherson strut assemblies incorporate a coil spring around the strut damper. True or False?
46. When the car is on the lift, grasping the front wheels and forcing them to turn rapidly can cause severe damage to this part:
    a. Wheel bearing.
    b. Suspension ball joint.
    c. Steering column or gear.
    d. Tie rod.
47. Vehicles equipped with MacPherson struts use __________ front suspension.

PROBLEM DIAGNOSIS

Suspension System

The suspension system problem diagnosis has been incorporated into the WHEEL ALIGNMENT, BEARING, AND TIRE PROBLEM DIAGNOSIS at the end of Chapter 32. Also, see STEERING SYSTEM PROBLEM DIAGNOSIS in this chapter.

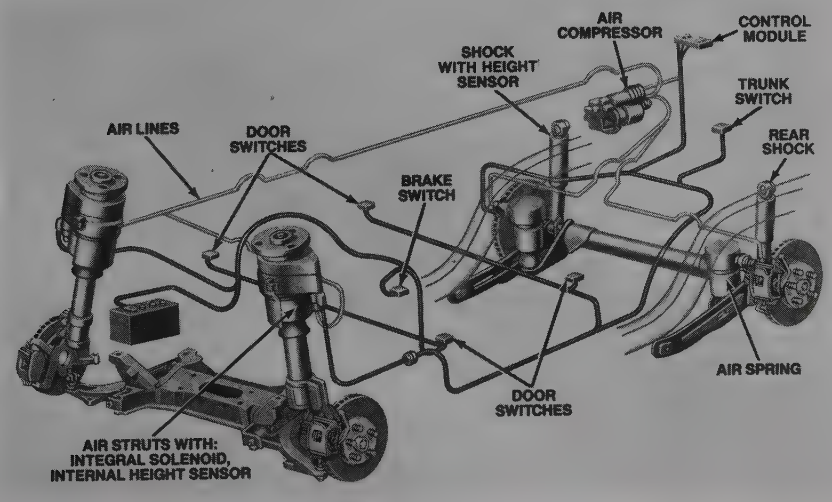


Fig. 33-124. Schematic depicting an adjustable air suspension system. Note air struts and shock absorbers, which house internal height sensors. (Chrysler)

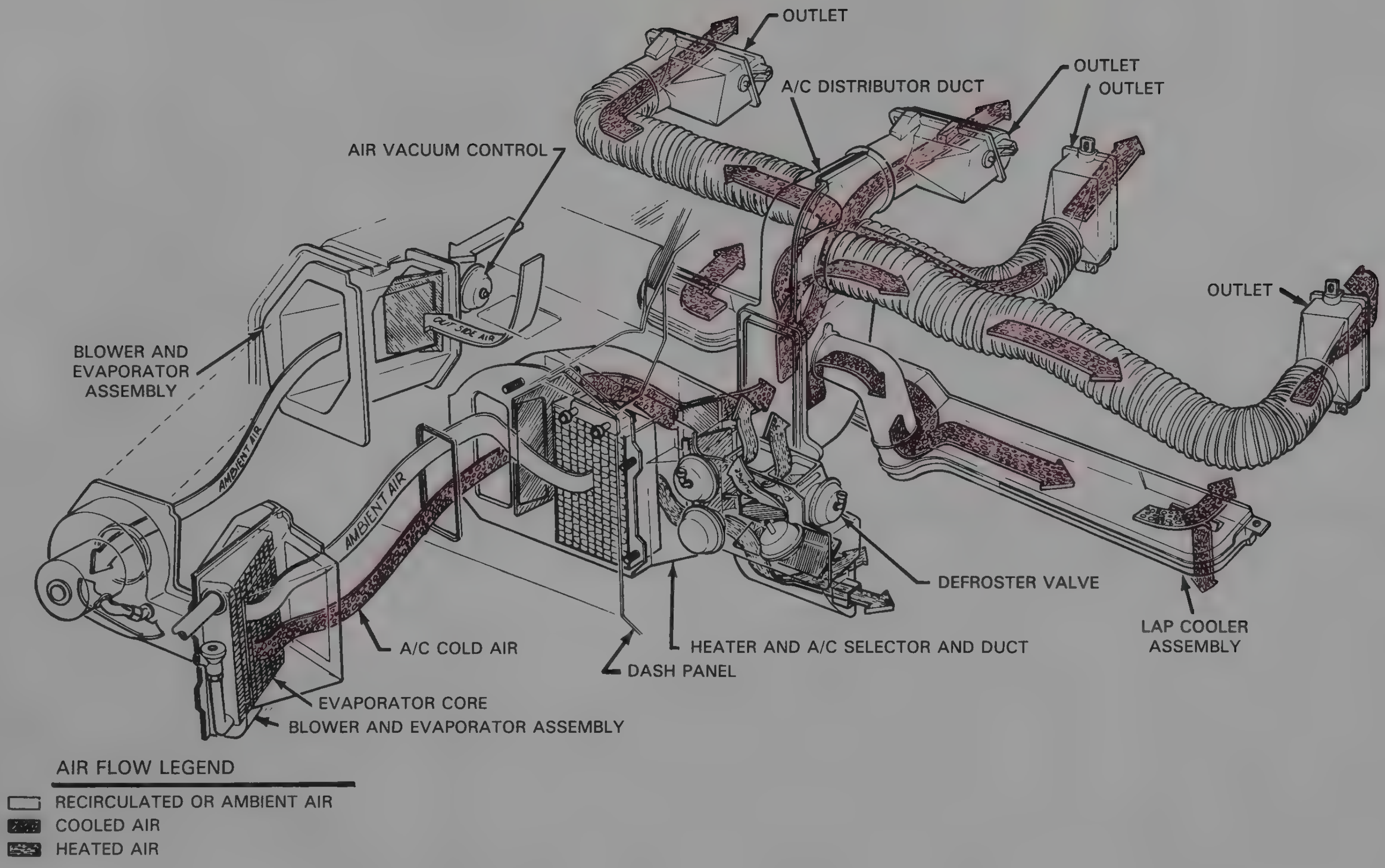
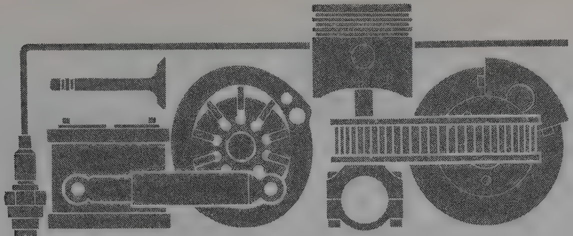

OUTLET
A/C DISTRIBUTOR DUCT
OUTLET
OUTLET
AIR VACUUM CONTROL
OUTLET
BLOWER AND EVAPORATOR ASSEMBLY
OUT SIDE AIR
AMBIENT AIR
AMBIENT AIR
DEFROSTER VALVE
LAP COOLER ASSEMBLY
A/C COLD AIR
HEATER AND A/C SELECTOR AND DUCT
DASH PANEL
EVAPORATOR CORE
BLOWER AND EVAPORATOR ASSEMBLY
AIR FLOW LEGEND
RECIRCULATED OR AMBIENT AIR
COOLED AIR
HEATED AIR

Fig. 34-1. Airflow in a fully automatic air conditioning system. (Chevrolet)



Chapter 34

AIR CONDITIONING, HEATER SERVICE

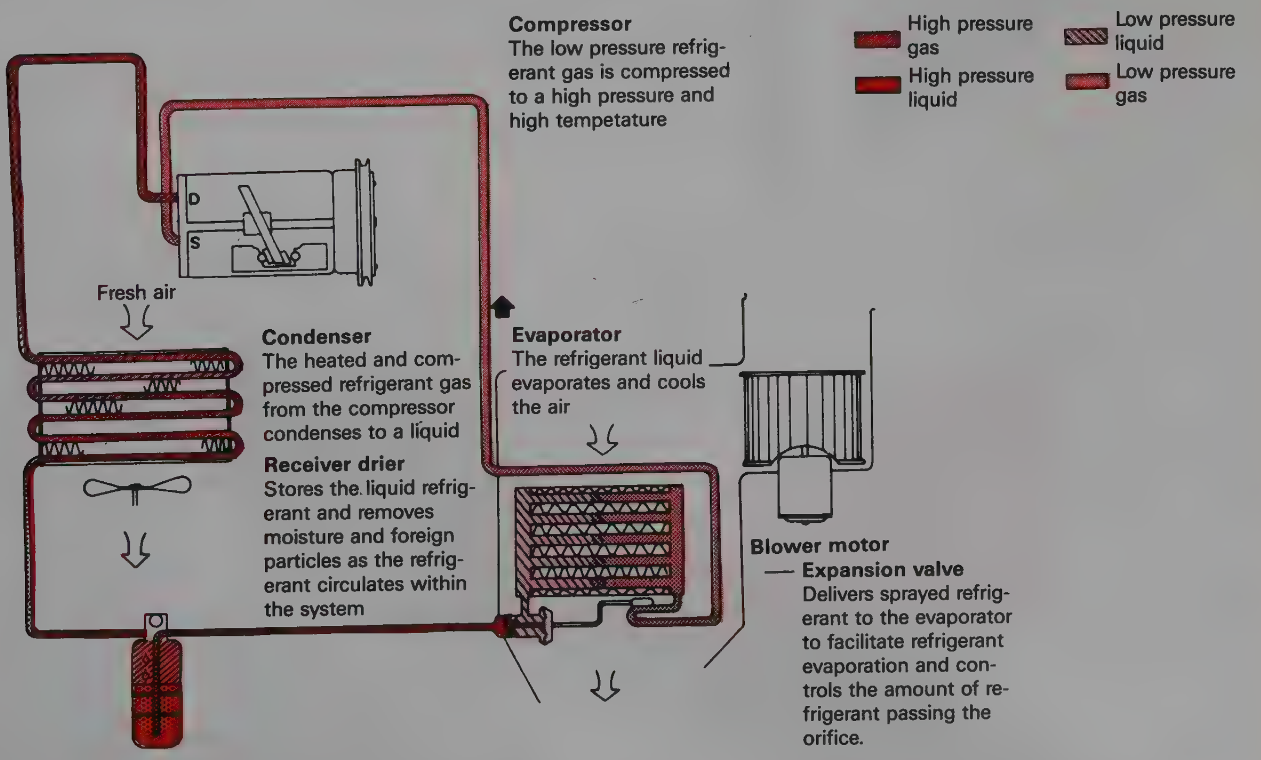
After studying this chapter, you will be able to:

- ☐ Explain basic refrigeration theory.
- ☐ Summarize the design, construction, and operation of major air conditioning system components.
- ☐ List the safety rules for air conditioning service.
- ☐ Inspect an air conditioning system for troubles.
- ☐ Discharge, evacuate, and recharge an air conditioning system.
- ☐ Service air conditioning and heater parts.
- ☐ Install air conditioning system parts.
- ☐ Service refrigerant oil.
- ☐ Diagnose air conditioning and heating problems.

AIR CONDITIONING

Basic air conditioning is a process in which air entering the car is cooled, cleaned, and dehumidified (moisture content lowered).

Originally, automobile air conditioning systems were manually controlled and were separate from the heating systems. Today, fully automatic systems, employing the reheat principle, are available. This type unit combines air cooling and heating into one system that will provide air at whatever temperature may be desired—summer or winter. Look at Fig. 34-1.



Compressor
The low pressure refrigerant gas is compressed to a high pressure and high tempetature

Condenser
The heated and compressed refrigerant gas from the compressor condenses to a liquid

Receiver drier
Stores the liquid refrigerant and removes moisture and foreign particles as the refrigerant circulates within the system

Evaporator
The refrigerant liquid evaporates and cools the air

Blower motor

Expansion valve
Delivers sprayed refrigerant to the evaporator to facilitate refrigerant evaporation and controls the amount of refrigerant passing the orifice.

Fig. 34-2. Schematic of refrigeration portion of a typical air conditioning system. Arrows indicate flow of Refrigerant-12. (Hyundai)

HOW AIR CONDITIONING WORKS

The parts making up a typical basic air conditioning system are pictured in Fig. 34-2. The various parts of the system are connected with tubing and flexible hose. The system is filled with a charge of Refrigerant-12 (Freon-12, Isotron-12, Prestone-12).

Figs. 34-2 and 34-3 illustrate the state (low or high pressure, gas, or liquid) of the Refrigerant-12 in various parts of the system during the refrigeration cycle.

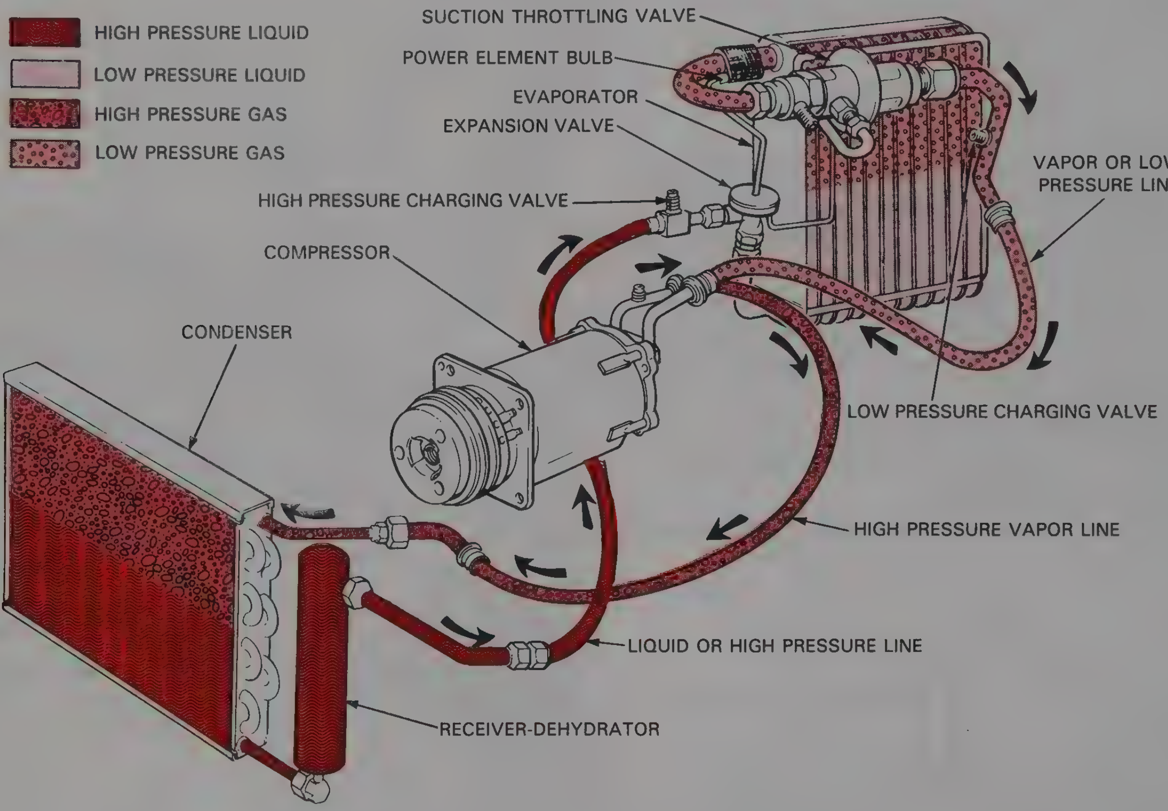

HIGH PRESSURE LIQUID
LOW PRESSURE LIQUID
HIGH PRESSURE GAS
LOW PRESSURE GAS
SUCTION THROTTLING VALVE
POWER ELEMENT BULB
EVAPORATOR
EXPANSION VALVE
HIGH PRESSURE CHARGING VALVE
COMPRESSOR
CONDENSER
VAPOR OR LOW PRESSURE LINE
LOW PRESSURE CHARGING VALVE
HIGH PRESSURE VAPOR LINE
LIQUID OR HIGH PRESSURE LINE
RECEIVER-DEHYDRATOR

Fig. 34-3. Refrigeration cycle. Note refrigerant state in various parts of system. (Ford)

REFRIGERANT-12

Refrigerant-12 will "boil" (vaporize) at −21.7°F (−29.8°C) at normal (sea level) atmospheric pressure. If under sufficient pressure, it will remain in the liquid state at temperatures exceeding those of the hottest day.

It is used over and over in the system and, unless contaminated with dirt, water, or air, will maintain its efficiency indefinitely. It is transparent and colorless in both the vapor and liquid state. Refrigerant-12 is nonpoisonous, except when in direct contact with an open flame. It is nonexplosive and nonflammable. Unless combined with moisture, it is noncorrosive. It is heavier than air and will become a vapor when released into the atmosphere. SEE SAFETY RULES ON REFRIGERANT-12 LATER IN THIS CHAPTER.

There is a distinct pressure-temperature relationship for Refrigerant-12. As the pressure is increased, the boiling point rises. Study the pressure-temperature chart in Fig. 34-4.

By lowering the pressure, the refrigerant may be made to boil. By increasing the pressure, the vaporized refrigerant may be returned to a liquid state. Study Fig. 34-3.

With the system operating, Fig. 34-3, high-pressure liquid refrigerant collects in the receiver-dehydrator. From the receiver, the refrigerant moves to the expansion valve, which reduces the pressure and meters low-pressure liquid refrigerant into the evaporator.

In the evaporator, the refrigerant is warmed by air passing over the coils. As more heat from the passenger compartment is absorbed, the refrigerant begins to boil (vaporize). By the time it reaches the outlet, the refrigerant is completely vaporized.

From the evaporator, the refrigerant vapor is forced through a suction throttling valve (on some systems), which controls evaporator temperature. Next, the refrigerant vapor is drawn into the compressor, which raises the pressure of the vapor and, at the same time, effects a rapid rise in temperature. The vapor is pumped to the condenser under 100 to 250 psi (690 to 1 724 kPa) pressure.

In the condenser, the hot, high-pressure refrigerant vapor gives up its heat to the airstream moving over the condenser fins. The change in temperature causes the refrigerant to return to its liquid state. Still under pressure from the compressor, the liquid refrigerant flows into the receiver-dehydrator for another cycle through the system.

To become familiar with the fundamentals of refrigeration, we will start with the receiver-dehydrator, Figs. 34-2 and 34-3.

RECEIVER-DEHYDRATOR (ACCUMULATOR)

The receiver-dehydrator acts as a reservoir for either pressurized LIQUID refrigerant, Fig. 34-5, or vapor, Fig. 34-6, depending upon system design. It may also

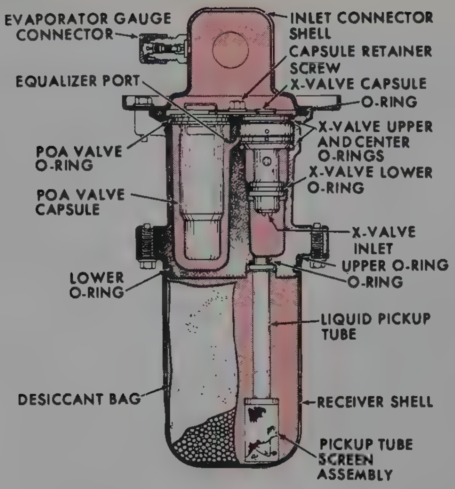

EVAPORATOR GAUGE CONNECTOR
EQUALIZER PORT
POA VALVE O-RING
POA VALVE CAPSULE
LOWER O-RING
DESICCANT BAG
INLET CONNECTOR SHELL
CAPSULE RETAINER SCREW
X-VALVE CAPSULE O-RING
X-VALVE UPPER AND CENTER O-RINGS
X-VALVE LOWER O-RING
X-VALVE INLET UPPER O-RING
O-RING
LIQUID PICKUP TUBE
RECEIVER SHELL
PICKUP TUBE SCREEN ASSEMBLY

Fig. 34-5. This receiver-dehydrator or VIR (valves in receiver) assembly also contains a POA suction throttling valve and an expansion valve. (Cadillac)

REFRIGERANT — 12
PRESSURE — TEMPERATURE
RELATIONSHIP

The table below indicates the pressure of Refrigerant — 12 at various temperatures. For instance, a drum of Refrigerant at a temperature of 26.6°C (80°F) will have a pressure of 579.9 kPa (84.1 psi). If it is heated to 51.6°C (125°F), the pressure will increase to 1,154.9 kPa (167.5 psi). It also can be used conversely to determine the temperature at which Refrigerant — 12 boils under various pressures. For example, at a pressure of 207.5 kPa (30.1 psi), Refrigerant — 12 boils at 0°C (32°F).

°C	°F	kPa	PSIG
-29.8	21.7	0	Atmospheric Pressure
-28.8	-20	16.5	2.4
-23.3	-10	31.0	4.5
-20.5	-5	46.9	6.8
-17.7	0	63.4	9.2
-15.0	5	81.4	11.8
-12.2	10	101.4	14.7
- 9.4	15	122.0	17.7
- 6.6	20	145.5	21.1
- 3.8	25	169.6	24.6
- 1.1	30	196.5	28.5
0	32	207.5	30.1
1.6	35	224.8	32.6
4.4	40	255.1	37.0
7.2	45	287.5	41.7
10.0	50	322.0	46.7

°C	°F	kPa	PSIG
12.7	55	358.5	52.0
15.5	60	397.8	57.7
18.3	65	439.2	63.7
21.1	70	482.7	70.1
23.8	75	530.2	76.9
26.6	80	579.9	84.1
29.4	85	632.3	91.7
32.2	90	686.7	99.6
35.0	95	745.3	108.1
37.7	100	806.0	116.9
40.5	105	870.2	126.2
43.3	110	937.7	136.0
46.1	115	1010.1	146.5
48.8	120	1083.2	157.1
51.6	125	1154.9	167.5
54.4	130	1234.2	179.0
60.0	140	1410.0	204.5

Fig. 34-4. Refrigerant pressure-temperature relationship. (Chevrolet)

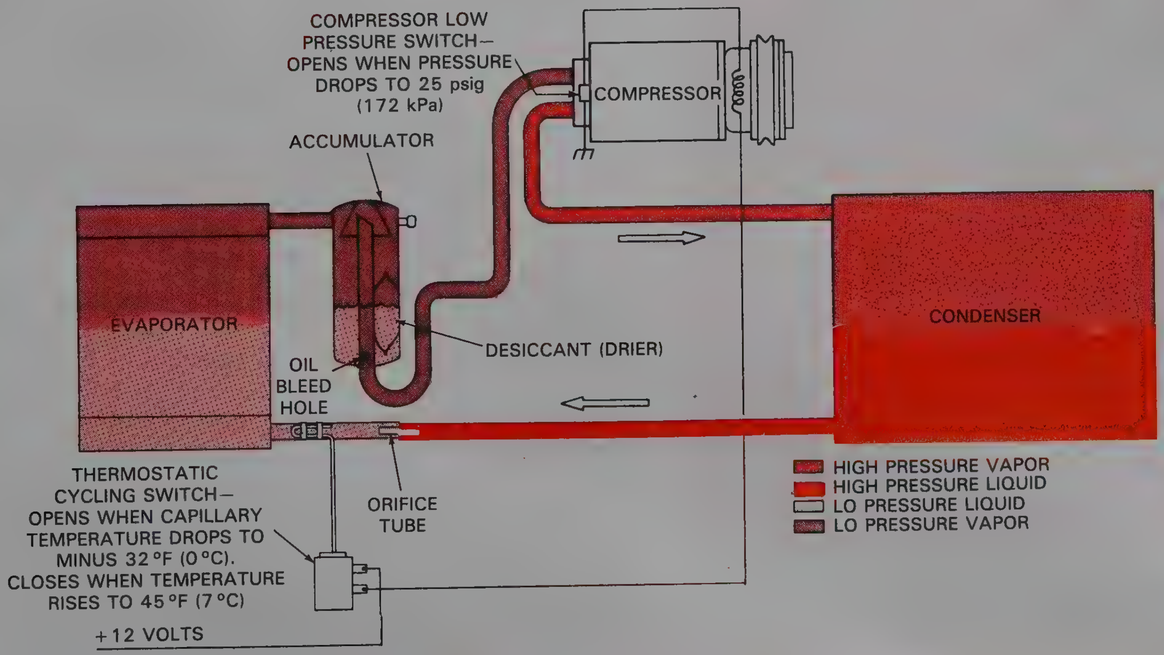

COMPRESSOR LOW PRESSURE SWITCH— OPENS WHEN PRESSURE DROPS TO 25 psig (172 kPa)
COMPRESSOR
ACCUMULATOR
EVAPORATOR
CONDENSER
DESICCANT (DRIER)
OIL BLEED HOLE
THERMOSTATIC CYCLING SWITCH— OPENS WHEN CAPILLARY TEMPERATURE DROPS TO MINUS 32 °F (0 °C). CLOSES WHEN TEMPERATURE RISES TO 45 °F (7 °C)
ORIFICE TUBE
+12 VOLTS
▨ HIGH PRESSURE VAPOR
🟥 HIGH PRESSURE LIQUID
☐ LO PRESSURE LIQUID
▨ LO PRESSURE VAPOR

Fig. 34-6. Air conditioning system using an orifice tube expansion valve. Note accumulator in system low side. Thermostatic switch cycles compressor to control cooling. (Cadillac)

be termed accumulator on some systems, Fig. 34-7. The receiver-dehydrator filters and removes moisture through means of a dessicant (drying agent). It may also incorporate both a POA (pilot operated absolute), expansion valve, and service fitting. See Fig. 34-2.

When the receiver becomes inoperative (dirty or moisture laden), some models require replacement while others permit part replacement.

The receiver may contain a fusible safety plug which releases pressure when refrigerant temperature exceeds a specified point (about 212°F or 100°C). When mounted on the low-side (between evaporator outlet and compressor), the receiver can incorporate a low-side pressure Schrader valve service fitting. A pressure cycling switch can also be used on such a setup.

When mounted on the high-side, the liquid refrigerant moves from the receiver-dehydrator through a flex line to the expansion valve. This line is called the LIQUID or HIGH PRESSURE line, Fig. 34-3.

Remember that when the receiver-dehydrator (accumulator) is located on the low-side, liquid refrigerant moves not from the receiver but directly from the condenser to the expansion valve. Refer to Fig. 34-6.

A low-side accumulator containing a filter screen, liquid bleed hole, dessicant, and pressure switch fitting is pictured in Fig. 34-7.

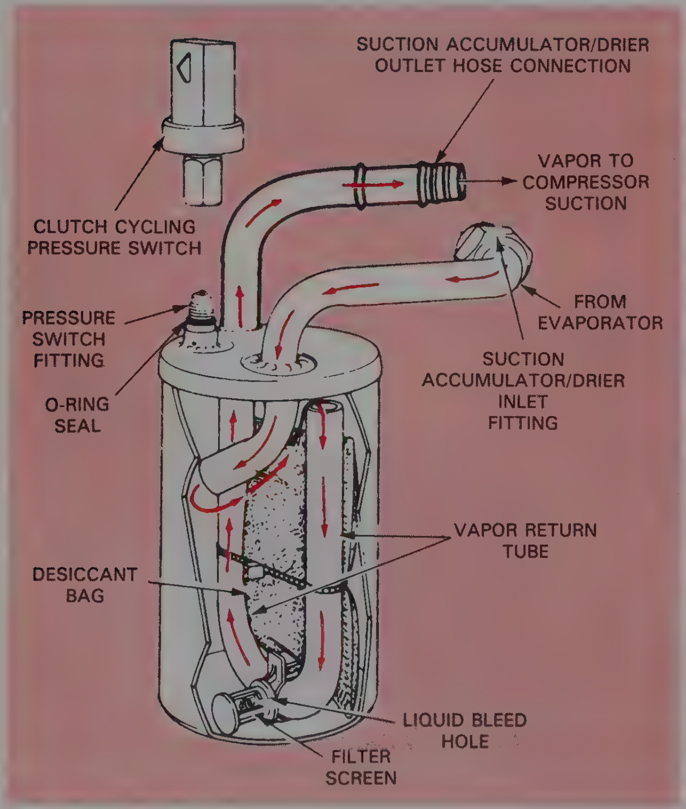

SUCTION ACCUMULATOR/DRIER OUTLET HOSE CONNECTION
VAPOR TO COMPRESSOR SUCTION
CLUTCH CYCLING PRESSURE SWITCH
FROM EVAPORATOR
PRESSURE SWITCH FITTING
SUCTION ACCUMULATOR/DRIER INLET FITTING
O-RING SEAL
VAPOR RETURN TUBE
DESICCANT BAG
LIQUID BLEED HOLE
FILTER SCREEN

Fig. 34-7. Accumulator-dehydrator. This particular unit is located in system low-pressure side, between evaporator and compressor. (Ford)

EXPANSION VALVE CONTROLS REFRIGERANT FLOW INTO EVAPORATOR

Refrigerant reaches the expansion valve (or orifice tube, depending on system design) as a high pressure liquid of moderate temperature.

The expansion valve admits a metered amount of refrigerant into the evaporator. The refrigerant moves into the evaporator as a relatively low temperature, low-pressure liquid.

A temperature sensitive power element bulb is attached to the evaporator outlet, Fig. 34-3. A capillary tube (length of tubing of small diameter which acts as a throttle on refrigerant) connects the bulb to the expansion valve. As the temperature of the evaporator outlet rises, the expansion valve is forced to admit a greater amount of refrigerant. When the temperature drops, the valve admits a lesser amount.

The action of the valve is also affected by spring and by evaporator pressure. Fig. 34-8 illustrates a typical thermostatic expansion valve.

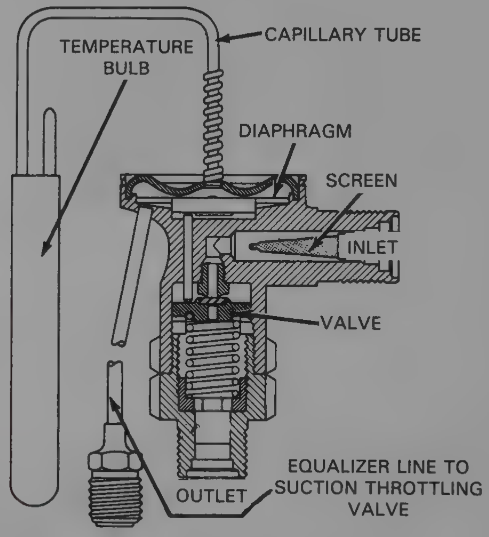
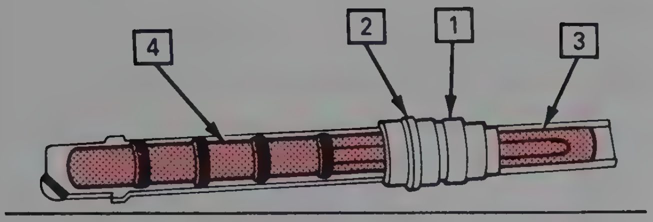

TEMPERATURE BULB
CAPILLARY TUBE
DIAPHRAGM
SCREEN
INLET
VALVE
OUTLET
EQUALIZER LINE TO SUCTION THROTTLING VALVE

Fig. 34-8. Typical thermostatic expansion valve. Note how valve is connected in Figs. 34-3, 34-10, 34-11, and 34-12. (Chevrolet)

Expansion valve servicing is usually limited to replacing the screen, and tightening of any connections which leak because of insufficient torque.

VARIABLE DISPLACEMENT ORIFICE TUBE (EXPANSION VALVE)

Some systems utilize an orifice tube as an expansion valve. The plastic or metal tube houses a fine screen and a small fixed orifice through which a metered flow of liquid refrigerant can pass, Fig. 34-9. The tube is placed in a line that travels from the condenser outlet



1 EXPANSION (ORIFICE) TUBE
2 O-RING
3 SHORT SCREEN (OUTLET — INSTALL TOWARDS EVAPORATOR)
4 LONG SCREEN (INLET — INSTALL TOWARDS CONDENSER)

Fig. 34-9. A variable displacement orifice tube (VDOT) unit. (Cadillac)

to the evaporator inlet. The fixed diameter of the tube restricts the high-pressure liquid refrigerant in the liquid line. This provides a low-pressure liquid flow to the evaporator.

Metal flakes may cause the expansion tube's screen to become clogged. If system diagnosis indicates that the tube is restricted, replacement may be necessary. Compressed air can be used to clean the screen if the tube frame is not broken and the screen is not torn. Fine, gritty particles, however, will not dislodge with compressed air. Follow the manufacturer's recommendations for specific cleaning instructions.

A typical CYCLING CLUTCH ORIFICE TUBE (often termed C.C.O.T.) system is illustrated in Fig. 34-6. Note that this specific version employs a thermostatic cycling switch. Note the use of a compressor low pressure switch to de-energize the compressor clutch if system pressure drops to 25 psig (pounds per square inch of gauge pressure) or 172 kPa. This provides compressor protection in event the system refrigerant charge is lost. It also prevents system operation when ambient air temperature is below freezing. Look at Fig. 34-6.

The orifice tube is not repairable. If defective, it must be replaced as a unit.

COOLING TAKES PLACE IN EVAPORATOR

As the low-pressure liquid refrigerant enters the evaporator from the expansion valve, it begins to vaporize (boil). This vaporizing action absorbs heat from the tubes and cooling fins.

The core tubes and fins are cold and air passing through the evaporator gives up heat to the core and a stream of cooled air enters the car.

When the air strikes the cold fins, some of the moisture in the air condenses and drains off the core. This produces a beneficial dehumidifying action.

Particles of dust, pollen, etc., tend to stick to the wet (from moisture condensation) fins and drain off with the water. This cleans a significant amount of pollutants from the cool air entering the car.

EVAPORATOR TEMPERATURE IS CRITICAL

Evaporator temperature generally will run from 33 to 60°F (1 to 16°C). If the temperature drops to freezing (32°F or 0°C), condensation on the evaporator core will freeze and block off the airflow.

Pressure in the evaporator must be controlled to prevent freezing. If pressure can be held between 29 and 30 psig (200 and 207 kPa), freezing will be eliminated. There are several methods of controlling evaporator icing.

EVAPORATOR ICING CONTROL

One technique used to prevent evaporator icing employs a THERMOSTATIC SWITCH that cuts out (stops driving) the compressor when evaporator core temperature drops to a specific point. When the temperature rises to a given level, the switch cuts in the magnetic clutch (on compressor) and the compressor is again driven. This on and off action of the compressor keeps the evaporator core cold and prevents freezing. See Figs. 34-6 and 34-10.

At one time, a HOT GAS BYPASS VALVE was used to prevent core icing. The valve was placed in the outlet side of the evaporator and metered a certain amount of high pressure, hot refrigerant (from the compressor) into the evaporator. This maintained the evaporator pressure at a point high enough to prevent icing. A typical hot gas bypass valve as used on older models is pictured in Fig. 34-11.

The SUCTION THROTTLING VALVE has superseded the hot gas bypass as a means of controlling evaporator pressure (temperature). The STV (suction throttling valve) is placed at the evaporator outlet. When evaporator pressure rises, the valve releases pressure into the low-pressure vapor line to the compressor. If the pressure drops down, the valve restricts the flow and builds evaporator pressure. The STV, Fig. 34-12, effectively controls core icing.

A modification of the STV is the POA (pilot operated absolute) SUCTION throttling valve. This valve design eliminates the diaphragm. It provides an accurate control over the evaporator pressure (29 psi plus or minus .5 psi or 200 kPa plus or minus 3.45 kPa), thus allowing the evaporator temperature to drop as low as possible without freezing.

A typical POA suction throttling valve is pictured in Fig. 34-13. Note the bronze bellows. The bellows contains a vacuum. The bellows operates the pilot needle valve. Movement (opening or closing) of the

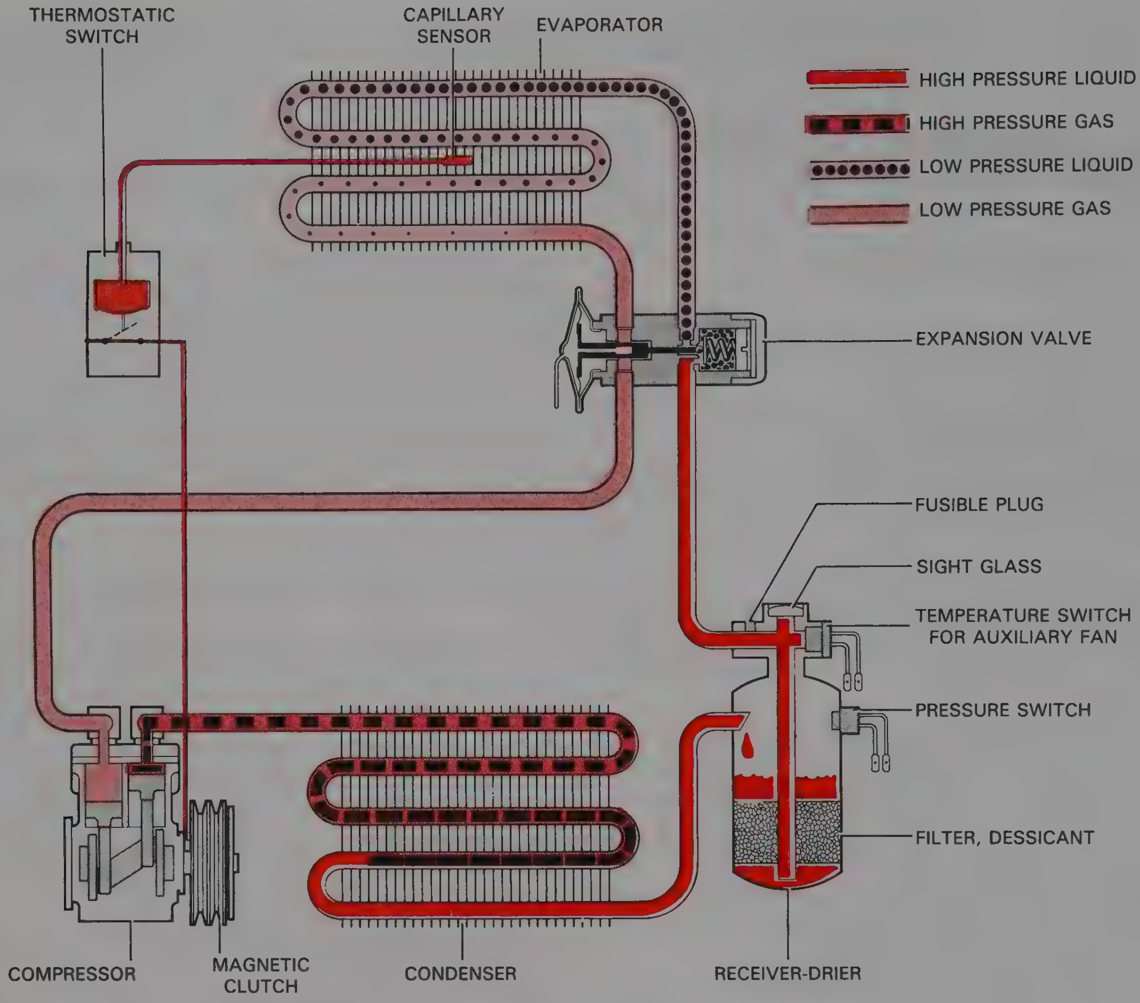

THERMOSTATIC SWITCH
CAPILLARY SENSOR
EVAPORATOR
HIGH PRESSURE LIQUID
HIGH PRESSURE GAS
LOW PRESSURE LIQUID
LOW PRESSURE GAS
EXPANSION VALVE
FUSIBLE PLUG
SIGHT GLASS
TEMPERATURE SWITCH FOR AUXILIARY FAN
PRESSURE SWITCH
FILTER, DESSICANT
COMPRESSOR
MAGNETIC CLUTCH
CONDENSER
RECEIVER-DRIER

Fig. 34-10. Evaporator icing in this system is controlled by a thermostatic switch that cycles compressor on and off. (Mercedes-Benz)

pilot needle alters the pressure on the compressor side of the piston in relation to pressure on the evaporator side. This in turn causes the piston to open and close the cylinder ports and maintain a constant evaporator pressure.

The system in Fig. 34-2 utilizes a POA suction throttling valve.

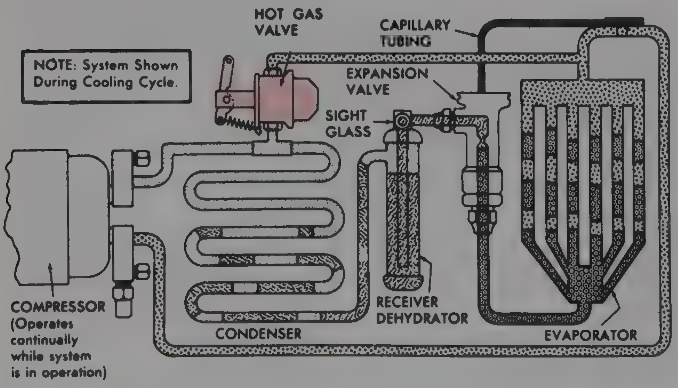

NOTE: System Shown During Cooling Cycle.
HOT GAS VALVE
CAPILLARY TUBING
EXPANSION VALVE
SIGHT GLASS
COMPRESSOR (Operates continually while system is in operation)
CONDENSER
RECEIVER DEHYDRATOR
EVAPORATOR

Fig. 34-11. Evaporator icing controlled with a hot gas bypass valve.

The air mixture or blending abilities of an airflow control system, such as pictured in Fig. 34-1, permits a discharge of temperature regulated air into the vehicle. This blending system will permit the evaporator to operate constantly near the freezing (icing) point, thus permitting full efficiency.

COMPRESSOR DRAWS IN AND COMPRESSES REFRIGERANT

The refrigerant leaves the evaporator as a LOW-PRESSURE VAPOR (around 12-50 psi or 83-345 kPa) and travels to the compressor through the flexible low-pressure vapor line. Look at Fig. 34-3.

The compressor draws in the vapor on the intake stroke. On the compression stroke, the vapor is forced through the high-pressure vapor line to the condenser.

BASIC COMPRESSOR DESIGNS

Some automotive air conditioning systems utilize the two cylinder, single-acting compressor. Single-acting,

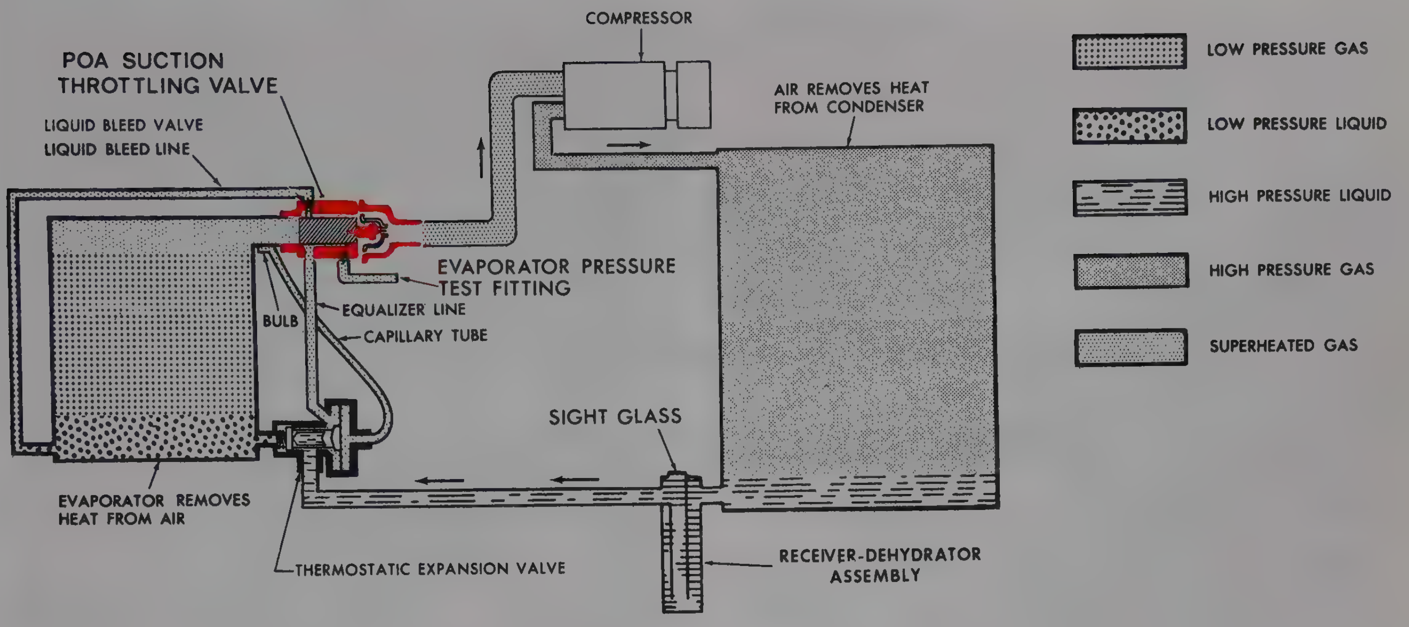

COMPRESSOR
POA SUCTION THROTTLING VALVE
LIQUID BLEED VALVE
LIQUID BLEED LINE
AIR REMOVES HEAT FROM CONDENSER
EVAPORATOR PRESSURE TEST FITTING
BULB
EQUALIZER LINE
CAPILLARY TUBE
SIGHT GLASS
EVAPORATOR REMOVES HEAT FROM AIR
THERMOSTATIC EXPANSION VALVE
RECEIVER-DEHYDRATOR ASSEMBLY
LOW PRESSURE GAS
LOW PRESSURE LIQUID
HIGH PRESSURE LIQUID
HIGH PRESSURE GAS
SUPERHEATED GAS

Fig. 34-12. Evaporator icing controlled with a POA (Pilot Operated Absolute) suction throttling valve. (Pontiac)

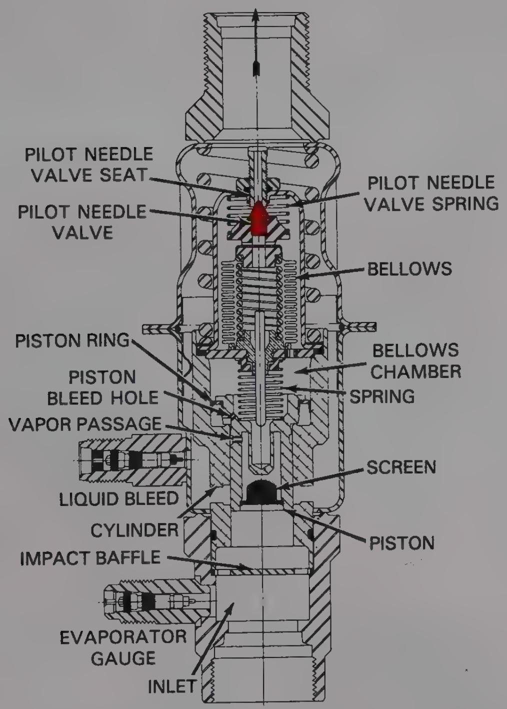

PILOT NEEDLE VALVE SEAT
PILOT NEEDLE VALVE
PILOT NEEDLE VALVE SPRING
BELLOWS
PISTON RING
BELLOWS CHAMBER
PISTON BLEED HOLE
SPRING
VAPOR PASSAGE
SCREEN
LIQUID BLEED
CYLINDER
PISTON
IMPACT BAFFLE
EVAPORATOR GAUGE
INLET

Fig. 34-13. Evaporator pressure is held to a constant pressure by this POA (Pilot Operated Absolute) suction throttling valve. (Cadillac)

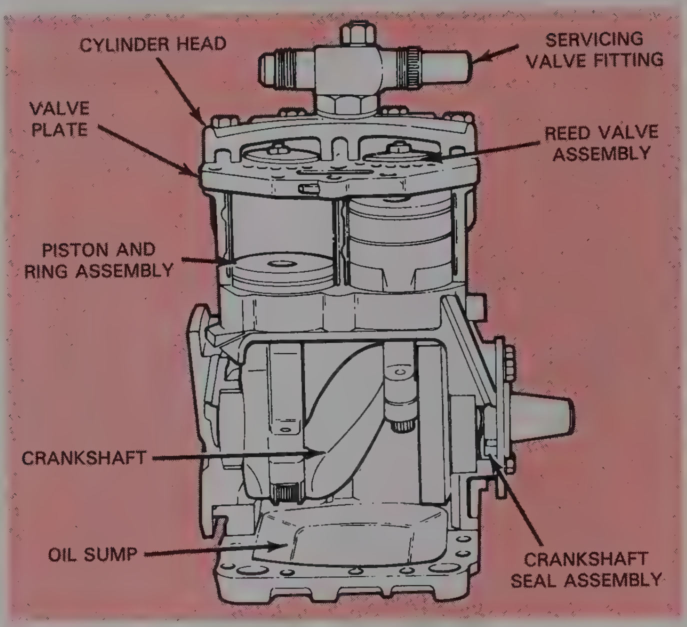

CYLINDER HEAD
SERVICING VALVE FITTING
VALVE PLATE
REED VALVE ASSEMBLY
PISTON AND RING ASSEMBLY
CRANKSHAFT
OIL SUMP
CRANKSHAFT SEAL ASSEMBLY

Fig. 34-14. Two cylinder, single-acting compressor. (Maserati)

in this case, means that the piston compresses the vapor on the upstroke only, Fig. 34-14.

Other air conditioning systems employ either a four cylinder, RADIAL compressor or the six cylinder, double-acting AXIAL type. Double-acting means that both ends of the piston draw in and compress vapor. In the axial type, the pistons are forced to move back and forth in an axial direction by the action of a rotating swash or wobble plate.

Fig. 34-15 illustrates the axial type compressor. Note that as the swash plate revolves, it forces the pistons to move back and forth. There actually are three double end pistons operating in six separate cylinders, hence the term six cylinder.

A five cylinder, variable displacement compressor is shown in Fig. 34-16. This "constant run" compressor can meet all air conditioning needs without cycling on and off.

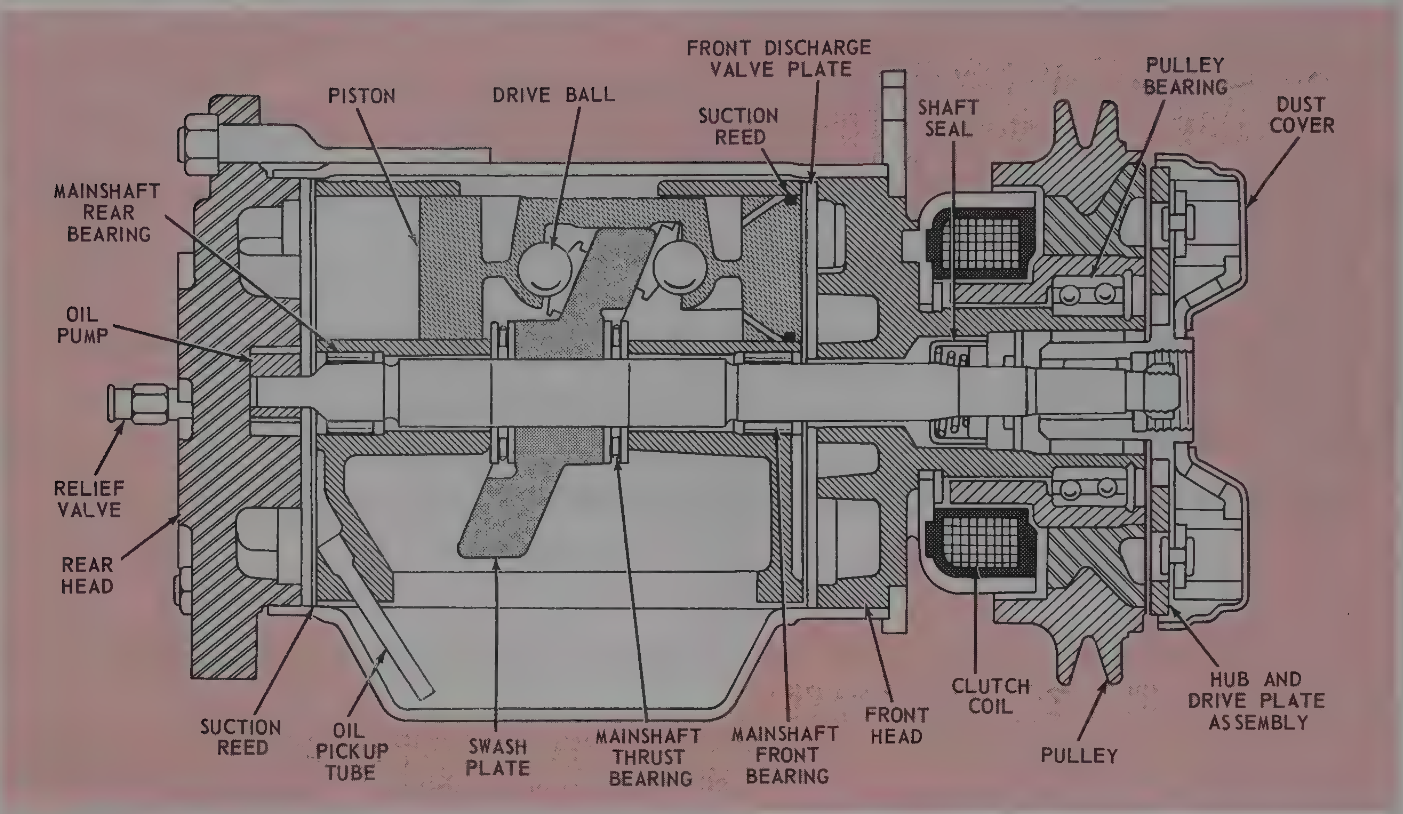

FRONT DISCHARGE VALVE PLATE
PISTON
DRIVE BALL
SUCTION REED
SHAFT SEAL
PULLEY BEARING
DUST COVER
MAINSHAFT REAR BEARING
OIL PUMP
RELIEF VALVE
REAR HEAD
SUCTION REED
OIL PICKUP TUBE
SWASH PLATE
MAINSHAFT THRUST BEARING
MAINSHAFT FRONT BEARING
FRONT HEAD
CLUTCH COIL
PULLEY
HUB AND DRIVE PLATE ASSEMBLY

Fig. 34-15. Typical six cylinder, double-acting, axial type compressor. Note "swash plate." (Deere & Co.)

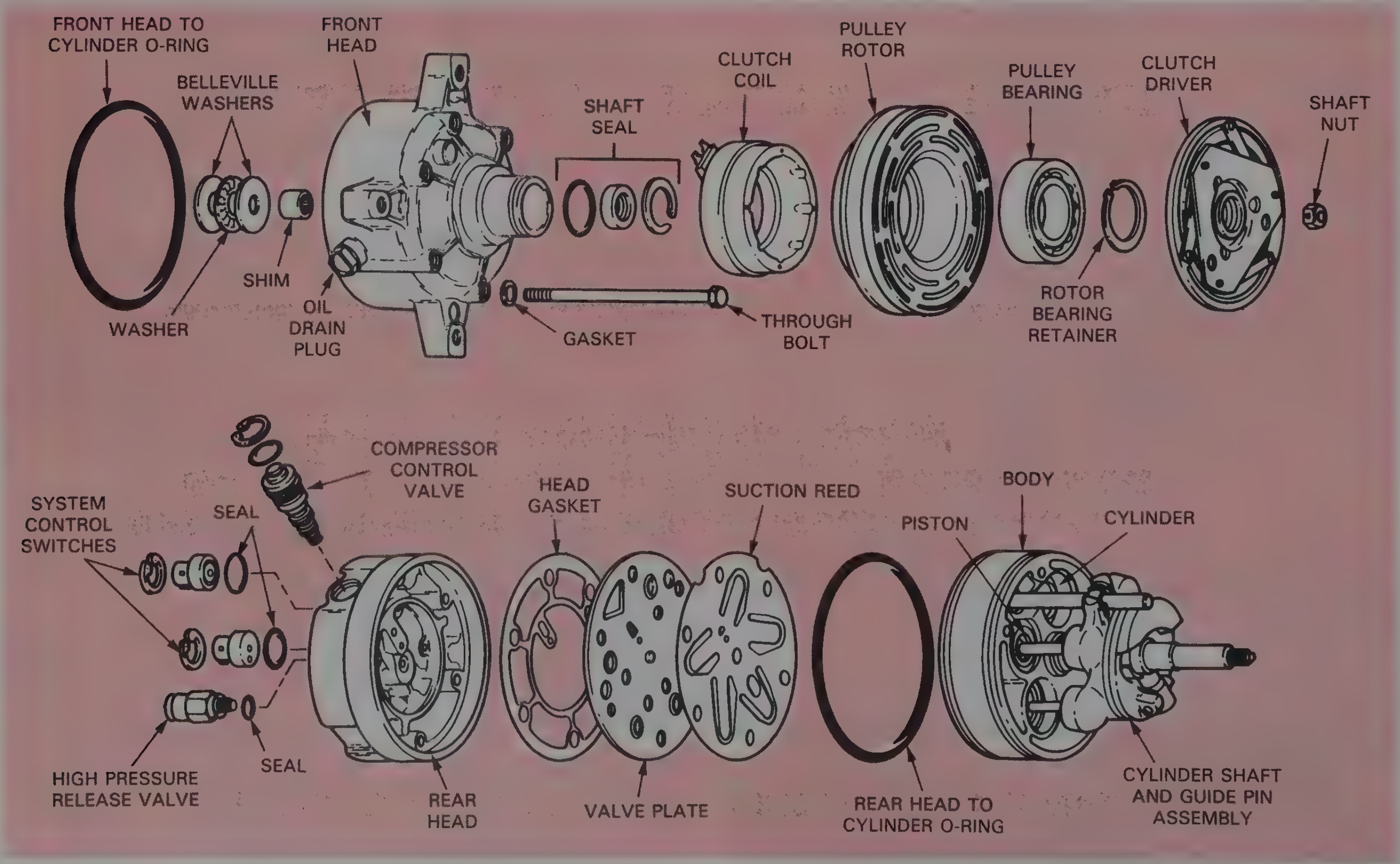

FRONT HEAD TO CYLINDER O-RING
BELLEVILLE WASHERS
FRONT HEAD
SHAFT SEAL
CLUTCH COIL
PULLEY ROTOR
PULLEY BEARING
CLUTCH DRIVER
SHAFT NUT
WASHER
SHIM
OIL DRAIN PLUG
GASKET
THROUGH BOLT
ROTOR BEARING RETAINER
COMPRESSOR CONTROL VALVE
SYSTEM CONTROL SWITCHES
SEAL
HEAD GASKET
SUCTION REED
BODY
PISTON
CYLINDER
HIGH PRESSURE RELEASE VALVE
SEAL
REAR HEAD
VALVE PLATE
REAR HEAD TO CYLINDER O-RING
CYLINDER SHAFT AND GUIDE PIN ASSEMBLY

Fig. 34-16. Exploded view of a five cylinder, variable displacement compressor. (Chevrolet)

Another compressor design makes use of rotary vanes.

The compressor can be equipped with a pressure relief valve. Under unusual conditions, the compressor pressure may exceed safe limits. If this happens, the relief valve will pop off and reduce pressure to a safe level. If the relief valve is forced open, the condition which is responsible should be corrected.

Some compressors are equipped with a low pressure switch to prevent compressor damage in the event the system charge is lost.

Compressor operation can also be controlled by a full throttle cut-off switch, anti-dieseling switch relay, or idle speed up solenoid in certain cases. Such controls are designed to improve engine operation (idle, shutdown, etc.).

COMPRESSOR IS BELT DRIVEN THROUGH MAGNETIC CLUTCH

To place the air conditioning system into operation, a compressor magnetic clutch is energized. The clutch coil draws the clutch hub inward, thus locking the revolving pulley to the compressor shaft.

Various designs are used for magnetic clutches. One type is shown on the compressor in Fig. 34-15.

CONDENSER CHANGES VAPOR TO LIQUID

The heated, high-pressure vapor from the compressor is forced into the condenser. As the vapor travels through the finned condenser coils, it gives up enough heat to the passing airstream to cause the vapor to return to the liquid state. As the liquid leaves the condenser, it is stored in the receiver-dehydrator.

The condenser is mounted in front of the radiator so it will be exposed to the stream of cooling air.

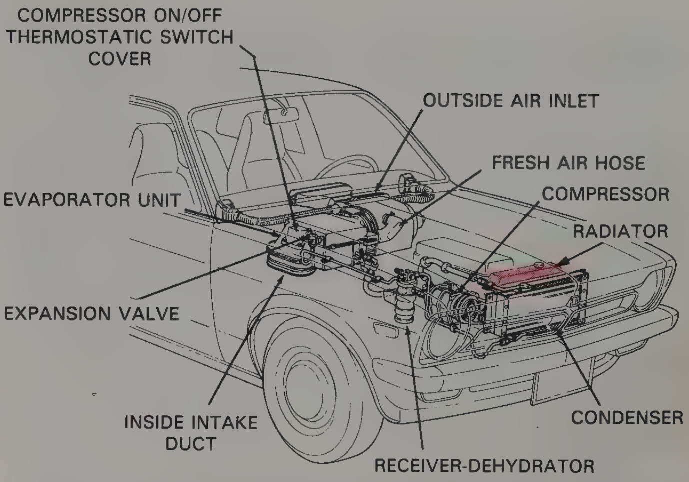


Fig. 34-17. The condenser is usually mounted in front of radiator. (GM)

Follow the path of the high-pressure vapor from the compressor as it travels through the condenser. Note how it changes into a liquid. See Figs. 34-3, 34-6, and 34-10.

Condensers (and evaporators) are often made of aluminum. Condenser pressures, during system operation, range from around 150 to 300 psi (1 034 to 2 069 kPa). Temperature varies from 120 to 200 °F (49 to 93 °C). A typical condenser, mounted in front of the radiator, is shown in Fig. 34-17.

MUFFLERS REDUCE SYSTEM NOISE

A small muffler is often placed between the compressor and the condenser to reduce pumping noise. A muffler may also be used to reduce line vibrations. Always install mufflers with the outlet side down so that refrigeration oil will not be trapped.

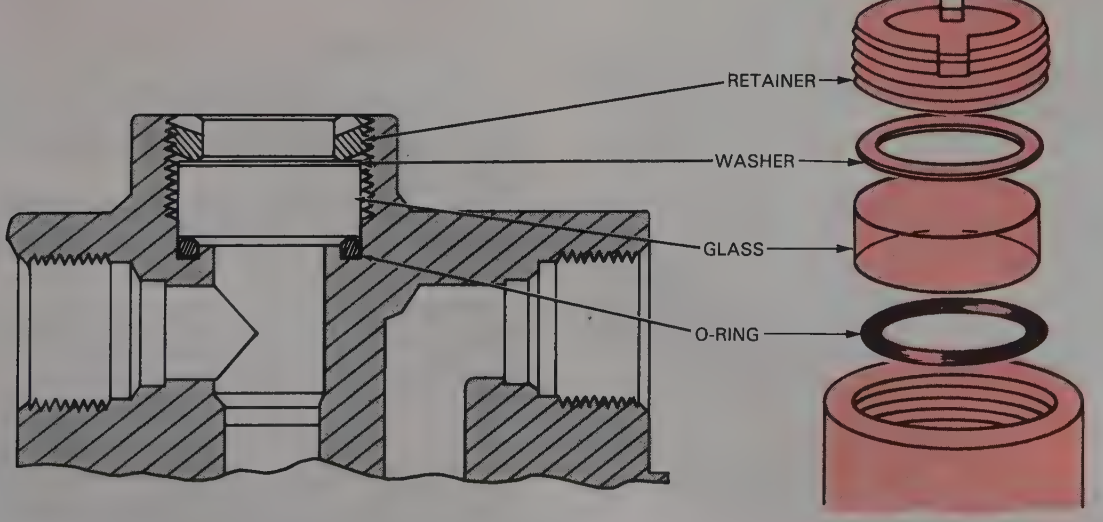


Fig. 34-18. Typical sight glass construction. (Chevrolet)

SIGHT GLASS PERMITS VISUAL OBSERVATION OF REFRIGERANT

A sight glass (incorporated in the receiver-dehydrator or set in high-pressure liquid line) may be used to inspect the refrigerant for the presence of bubbles or foam. One type of sight glass construction is shown in Fig. 34-18. A sight glass also appears in Figs. 34-10 and 34-12.

Use of the sight glass is covered under system service later in this chapter.

REFRIGERATION CYCLE

The refrigerant moves from the receiver-dehydrator to the expansion valve as a high-pressure liquid. The expansion valve admits a controlled amount of liquid into the evaporator. As the liquid passes through the expansion valve into the evaporator, the pressure is greatly reduced.

The low-pressure refrigerant boils or vaporizes inside the evaporator, thus drawing heat from the evaporator core. Air passing over the evaporator core is cleaned, cooled, and dehumidified.

The low-pressure liquid in the evaporator leaves the evaporator as low-pressure vapor.

The compressor draws in low-pressure vapor and compresses it into high-pressure vapor.

The high-pressure vapor from the compressor then moves into the condenser. As it passes through the condenser coils, it gives up much of its heat to the passing air. This changes the vapor back into a high-pressure liquid.

The high-pressure liquid from the condenser then moves into the receiver-dehydrator. From the receiver-dehydrator, the refrigerant begins another cycle through the system.

AIR CONDITIONING SYSTEM SERVICE

For the remainder of this chapter, we will be concerned with common air conditioning service procedures. Most procedures covered will apply to systems regardless of make or model.

Refrigerant-12, under the proper circumstances, can be extremely dangerous. Study the following safety rules concerning the air conditioning system. Memorize and observe all of these precautions. Fig. 34-19 illustrates two "SAFETY TOOLS" that can help prevent painful and serious injury.

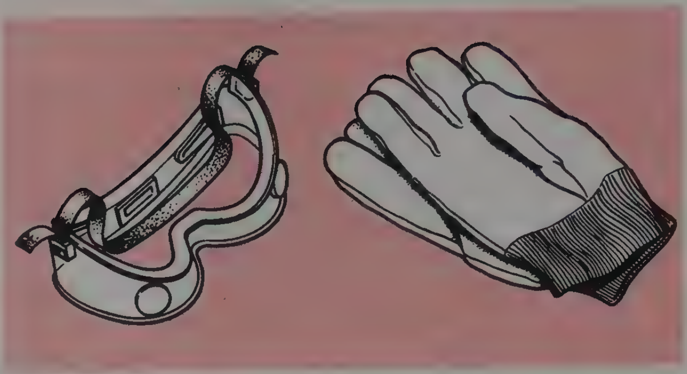


Fig. 34-19. An air conditioning specialist's "best friends." Use them! (Jaguar)

SAFETY RULES

1. ALWAYS WEAR PROTECTIVE GOGGLES WHEN SERVICING THE REFRIGERATION SYSTEM.

When Refrigerant-12 is released into the atmosphere (room), it will evaporate so fast that it will freeze the surface of objects it contacts. If it strikes the eyes, this rapid freezing action can cause serious eye injury.

If through carelessness, refrigerant is allowed to contact your eyes, take the following steps:

1. Do not panic.
2. Splash large amounts of water (90 to 100°F or 32 to 38°C) into eyes to raise temperature. Do not rub.
3. Apply several drops of sterile (clean) mineral oil to each eye.
4. Consult an eye specialist immediately — even if the pain has passed.

2. SERVICE AREA MUST BE WELL VENTILATED.

An ample supply of fresh air in the work area will prevent the chance of suffocation if a great deal of refrigerant displaces the air. It will also help to prevent poisoning by breathing the fumes caused by allowing refrigerant to contact an open flame.

3. NEVER DISCHARGE REFRIGERANT-12 DIRECTLY INTO SERVICE AREA.

Refrigerant will vaporize at room temperature. Since it is heavier than air, it will settle down. If enough refrigerant is discharged into an area without proper ventilation, it may displace the air and cause suffocation.

When refrigerant is discharged into the service area, there is a danger that it may contact an open flame and produce poisonous phosgene gas.

Always discharge the system into the service area exhaust system. If no such system is available, discharge the system outside the building.

4. NEVER SUBJECT SYSTEM TO HIGH TEMPERATURES.

Never steam clean, weld, bake body finishes, etc., on or near the air conditioning refrigeration system. To do so can cause a dangerous rise in system refrigerant pressure.

5. KEEP REFRIGERANT AWAY FROM SKIN.

If refrigerant contacts your skin, treat in the manner recommended for the eyes (Rule 1). When cracking fittings or making connections, wear a pair of protective gloves and cover the fitting with a loose cloth.

6. NEVER LEAVE REFRIGERANT DRUM UNCAPPED.

The refrigerant supply drum valve and safety plug is protected with a screw cap. This cap should be replaced immediately after use of the drum. Keep cap in place when drum is in storage or is being moved.

7. DO NOT SUBJECT REFRIGERANT SUPPLY TANK OR SMALL CANS TO EXCESSIVE HEAT.

Dangerous internal pressures can be reached quickly if drum is subjected to excessive heat. Safety plug could fail, causing drum to burst in a violent manner. Keep containers upright while charging system.

When heating drum during system charging (usually necessary), never heat with anything but warm water or warm wet rags (not over 125°F or 52°C). Never use a torch, stove, etc., to heat drum.

8. DO NOT FILL TANK COMPLETELY.

When filling a small tank from a larger one, do not completely fill the tank. Allow ample space for refrigerant expansion due to heating. A full tank can be dangerous.

9. NEVER BREATH THE SMOKE PRODUCED WHEN R-12 CONTACTS A FLAME.

When Refrigerant-12 contacts a flame, it creates phosgene — a poisonous gas.

10. NEVER CONNECT AN R-12 CONTAINER, SUCH AS ONE POUND CANS, TO THE SYSTEM HIGH PRESSURE SIDE. REFRIGERANT CAN FLOW BACK FROM THE SYSTEM INTO THE CONTAINER. THIS CAN CAUSE THE CONTAINER TO EXPLODE VIOLENTLY.

11. WHEN TRANSPORTING R-12 CONTAINERS, PLACE IN CAR TRUNK OR PICKUP BED. NEVER PLACE IN PASSENGER COMPARTMENT.

If in open bed, protect from sun to prevent overheating and blowing of safety plug.

GENERAL SERVICE PRECAUTIONS TO PREVENT CONTAMINATION OF REFRIGERATION SYSTEM

The refrigeration system will not tolerate dirt, air, or moisture. The system must be chemically stable (contains only pure Refrigerant-12 and a small quantity of pure compressor oil) to function as designed.

The presence of air, dirt, or moisture can cause sludging, corrosion, freezing of the expansion valve, and other troubles.

In order to insure the chemical stability of the system, always observe the following general service precautions:

1. Service tools should be spotlessly clean and dry.
2. Before disconnecting, thoroughly clean outside of fitting. Use a clean cloth dampened with alcohol. Be careful not to spill alcohol on car's painted surfaces.
3. Refrigerant lines should be close to room temperature before disconnecting. This will help prevent condensation from forming inside the line.
4. As soon as a line or part is disconnected, cap it to prevent the entry of oil, dirt, moisture, or other foreign material. See Fig. 34-20.

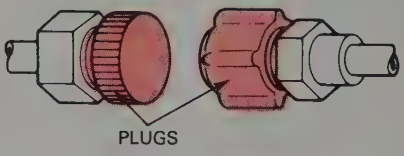


Fig. 34-20. When lines are opened, immediately close with plugs or caps such as these. This keeps dirt and moisture out. (Nissan)

5. Replacement lines and parts should be at room temperature before removing sealing caps to prevent condensation formation.
6. Do not remove sealing caps from lines or parts until ready to connect into the system.
7. If parts have become contaminated and flushing is indicated, flush with either Refrigerant-12 or with dry nitrogen.
8. Connect the receiver-dehydrator into the system LAST. This will insure maximum moisture protection.
9. Avoid keeping the system "open" (part or line disconnected) for longer than five minutes. Plan the work and lay out parts so the system will be open for as short a period of time as possible to prevent entry of moisture.
10. Keep compressor oil free of moisture. When using a container for compressor oil, the container must be clean and dry. Compressor oil is quite moisture free and will absorb any moisture it contacts.
11. Compressor oil containers should be kept capped. Do not open the oil container until ready to use. Cap immediately following use to prevent entry of dirt or moisture.
12. Always evacuate (draw out with a vacuum) the system to remove air and moisture before charging (filling with refrigerant) the system.

HOSE, TUBING, AND FITTING SERVICE PRECAUTIONS

Always discharge the system before opening a connection. Clean connections before "cracking" (opening). Following discharge, crack the connection open. If ANY pressure is evident, allow it to bleed off (seep out slowly) before completely separating the connection.

Cap or plug lines and parts as soon as disconnected. Use suitable plugs as shown in Fig. 34-20.

Remove caps from either new or used components just before installation.

If tubing must be bent, use a suitable tubing bender to avoid kinking. Do not try to rebend formed (already bent in a specific shape) lines.

Avoid sharp bends. General practice calls for hose bends with a bend radius from five to ten times the diameter of the hose, depending on hose construction. The larger the bend, within reason, the better.

Keep hose at least 3 in. (80 mm) away from the exhaust system unless special heat shields are used.

Use new O-rings. Make certain O-rings are the correct size and properly positioned. Coat both fitting and O-ring with refrigerant oil before assembly. When a connection is made without applying refrigeration oil, it will probably leak. Connection must be properly aligned, clean, and free of nicks or burrs. See Figs. 34-21 and 34-22.

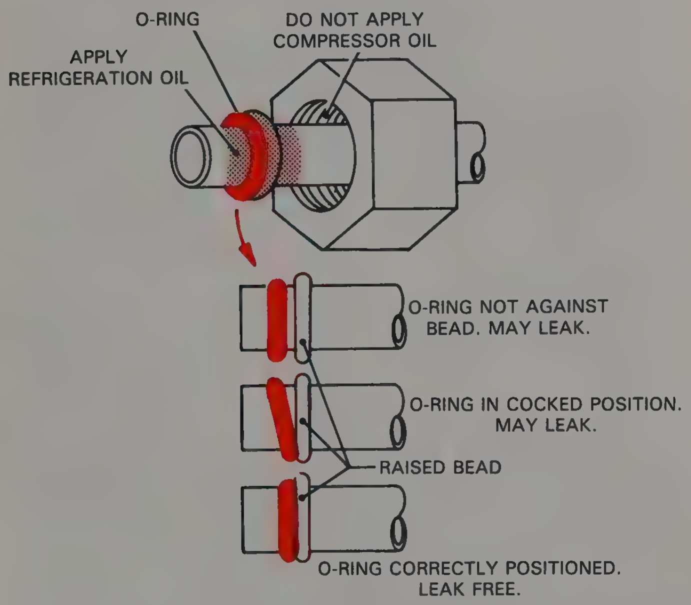

O-RING
DO NOT APPLY COMPRESSOR OIL
APPLY REFRIGERATION OIL
O-RING NOT AGAINST BEAD. MAY LEAK.
O-RING IN COCKED POSITION. MAY LEAK.
RAISED BEAD
O-RING CORRECTLY POSITIONED. LEAK FREE.

Fig. 34-21. When assembling fittings such as this, always coat O-ring and immediate area with fresh, clean refrigeration oil. Make sure O-ring is correctly positioned. (Nissan)

Torque the connection. Proper torquing to specifications is very important. Remember that aluminum and copper connections require LESS TORQUE THAN STEEL connections.

If one end of the connection is steel and the other aluminum or copper, torque to aluminum or copper specifications only.

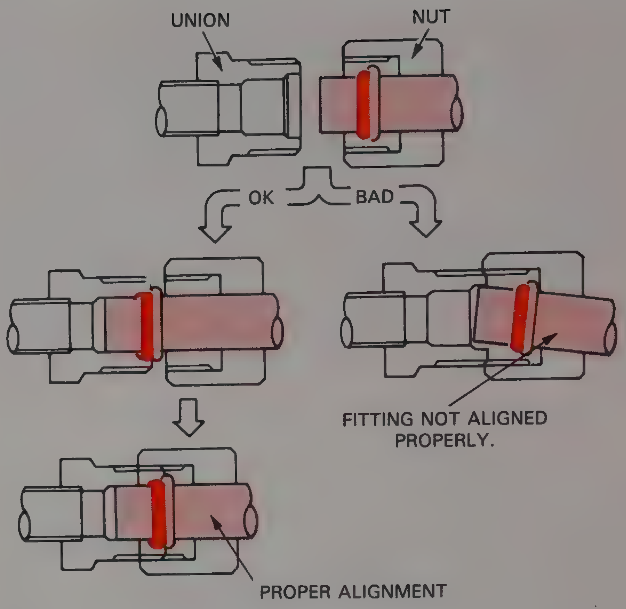


Fig. 34-22. Fittings must be properly aligned or they will leak. (Nissan)

Metal Tube Outside Diameter	Thread and Fitting Size	Steel Tubing Torque		Aluminum or Copper Tubing Torque		Nominal Torque Wrench Span
		N·m	LB. FT.	N·m	LB. FT.	
1/4	7/16	17	13	8	6	7/16 and 9/16
3/8	5/8	45	33	17	12	5/8 and 3/4
1/2	3/4	45	33	24	18	3/4 and 7/8
5/8	7/8	45	33	33	24	7/8 and 1 1/16
3/4	1 1/16	45	33	41	31	1 1/16 and 1 1/4

Fig. 34-23. Refrigeration system tubing connection torque table as used by one company. Note that torque figures are based on tubing material as well as tubing diameter. (Chevrolet)

A typical torque table used by one company, is shown in Fig. 34-23. Note that the table is based on the tube material as well as diameter.

Recommended torque value for the various connections, using O-rings in one specific system, is shown in Fig. 34-24.

When tightening or loosening connections, always use two wrenches to avoid twisting the tubing. Note Fig. 34-25. It shows one nut being held with an open end wrench while the other nut is being tightened with a torque wrench. A flare nut (tubing) wrench will hold better than an open end and will be less likely to deform the nut.

To pull a hose attached with a hose clamp, remove the clamp and make an angular cut as shown in A, Fig. 34-26. The hose may then be pulled. Do not nick the fitting with the knife.

When installing hose utilizing a clamp, coat hose and tube with refrigeration oil. Then slide the hose over the tube sealing beads and up to the locating bead, E,

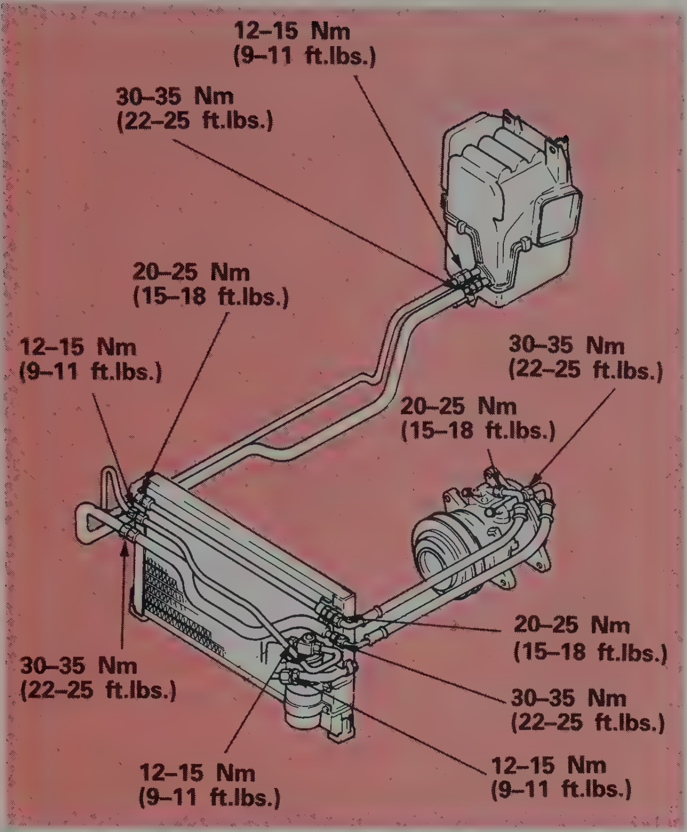

12–15 Nm
(9–11 ft.lbs.)
30–35 Nm
(22–25 ft.lbs.)
20–25 Nm
(15–18 ft.lbs.)
12–15 Nm
(9–11 ft.lbs.)
30–35 Nm
(22–25 ft.lbs.)
20–25 Nm
(15–18 ft.lbs.)
20–25 Nm
(15–18 ft.lbs.)
30–35 Nm
(22–25 ft.lbs.)
30–35 Nm
(22–25 ft.lbs.)
12–15 Nm
(9–11 ft.lbs.)
12–15 Nm
(9–11 ft.lbs.)

Fig. 34-24. Torque all connections as specified by maker. (Dodge)

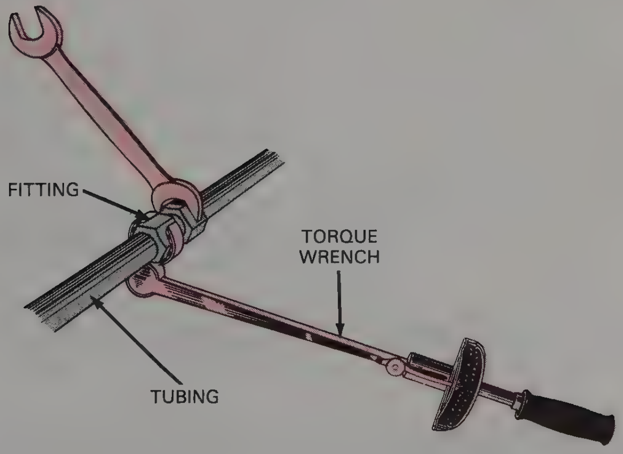

FITTING
TORQUE WRENCH
TUBING

Fig. 34-25. Use TWO wrenches when tightening or loosening a connection. Use torque wrench when tightening. (Harrison)

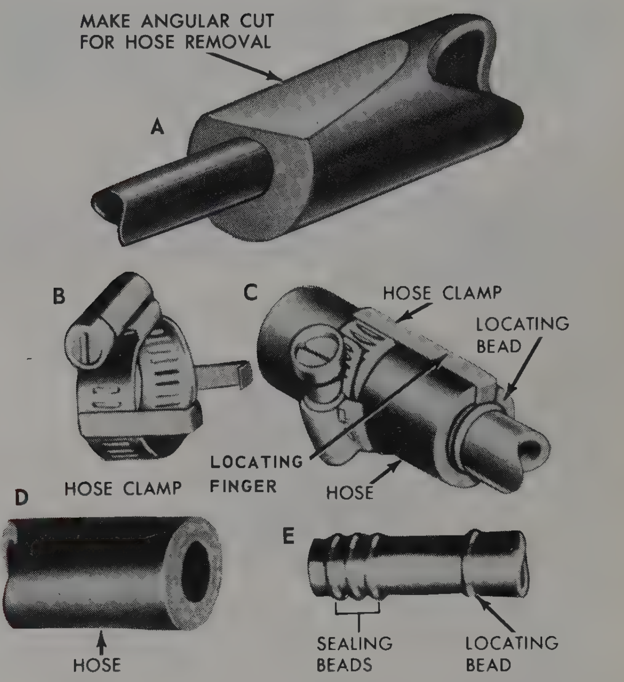
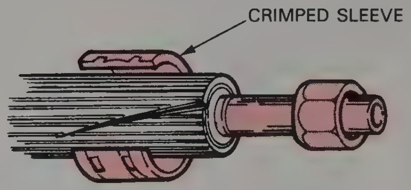

MAKE ANGULAR CUT FOR HOSE REMOVAL
A
B
C
HOSE CLAMP
LOCATING BEAD
LOCATING FINGER
HOSE
D
HOSE CLAMP
HOSE
E
SEALING BEADS
LOCATING BEAD

Fig. 34-26. Hose removal and installation where a hose clamp is employed. A—Cut hose for easy removal. B—Hose clamp. C—Hose clamp positioned so that locating fingers are touching locating bead. D—Hose. E—End of tubing showing sealing and locating beads. (Chevrolet)

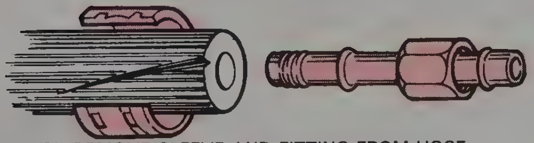
Fig. 34-26. Position the clamp B, as shown in C. Note how the locating bead in C is used to position the clamp. The clamp screw should be torqued. Following the first 1000 miles (1 610 km) of operation, torque clamp screws again.

Some hoses are assembled with sleeves. Fig. 34-27 illustrates the repair procedure involved in hose replacement on such a setup.

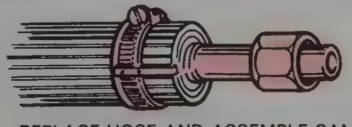
To replace a defective fitting on a sleeve arrangement, cut off the hose directly behind the sleeve. Lube a new service fitting with refrigerant oil and insert into hose. Install a hose clamp, position, and tighten to specs. Look at Fig. 34-28.


CRIMPED SLEEVE

(A) SAW SLEEVE AND DEFECTIVE HOSE THROUGH FIRST WRAP

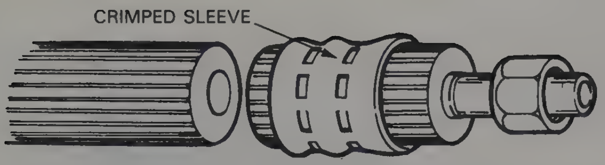


(B) REMOVE SLEEVE AND FITTING FROM HOSE

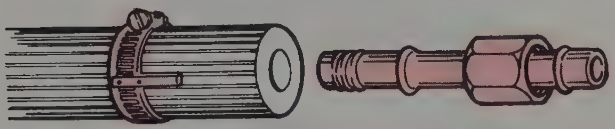


(C) REPLACE HOSE AND ASSEMBLE SAME FITTING WITH SERVICE BAND CLAMP

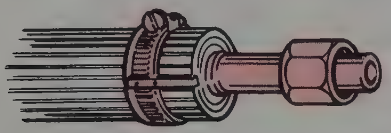
Fig. 34-27. Replacing a defective hose where a crimped sleeve has been used. (Buick)



(A) REMOVE 1-3/4 IN. (44 mm) OF HOSE WITH DEFECTIVE FITTING



(B) INSERT SERVICE FITTING



(C) ASSEMBLE WITH SERVICE CLAMP

Fig. 34-28. Replacing a defective fitting where a crimped sleeve has been used. (Pontiac)

Other setups may employ a spring lock coupling. This type holds the two parts together through the use of a garter spring that snaps over a flare on the female fitting end. O-rings seal against leakage. The separation of these spring lock couplings requires the use of a special removal tool. Fig. 34-29 illustrates the spring lock coupling and correct technique used to either connect or disconnect it.

When replacing a hose, be sure to use a specified type hose for refrigeration systems. Reinstall all hose clamps, tubing clamps, and insulators to prevent vibration and other damage.

Be careful in the selection of tape when taping hoses to prevent vibration or to hold away from hot areas. Some plastic tapes are not compatible with certain hose compounds. If used, they will cause serious deterioration of the hose.

Always check all connections for leaks after the system has been charged.

MANIFOLD GAUGE SET

A manifold gauge set is needed for charging a system, checking system pressure, and other operations. It consists of two gauges set in a manifold containing two gauge valves and three outlet connections. See Fig. 34-30.

The low-pressure gauge is graduated in psi in one direction and in inches of vacuum in the other.

The center manifold connection is common to both valves. It is used for attaching a hose for charging with refrigerant, attaching to a vacuum pump for system evacuation, or for injecting oil into the system.

Note in Fig. 34-30, that the center connection can be closed or opened to either of the side connections by opening (counterclockwise) or closing (clockwise) the valves. Also note that even with the valves shut, the gauges are always open to pressure from the side connections.

SYSTEM USING SCHRADER VALVE GAUGE SERVICE FITTINGS

A Schrader valve is a spring-loaded valve that permits the connection of gauge lines into a system not using service fittings equipped with hand-operated valves. A typical Schrader valve is shown in Fig. 34-31. This valve is mounted in a suction throttling valve.

Both Schrader valves may be located on the compressor (one on suction side and other on discharge side) or one Schrader valve may be located on the suction throttling valve and the other on the compressor discharge (high pressure) side. On setups using a suction accumulator, Fig. 34-7, a Schrader service fitting is located on the accumulator (low side of this system).

A special adapter is required to connect the manifold gauge set hose ends to the Schrader valves. When connecting gauge lines to Schrader valves, use a piece of heavy cloth to divert any refrigerant that may escape. Wear gloves and goggles.

CAUTION: WHEN DISCONNECTING GAUGE LINES FROM SCHRADER VALVES, DISCONNECT ADAPTER FROM VALVE (SERVICE FITTING) FIRST. NEVER DISCONNECT ADAPTER FROM GAUGE LINE UNTIL ADAPTER IS REMOVED FROM VALVE! DO NOT REMOVE CHARGING HOSE AT GAUGE SET UNTIL REMOVED FROM SYSTEM.

Connect the low-pressure compound gauge (marked in psi and inches of vacuum) to the valve in the low-pressure (vapor) side of the system. Connect the high-pressure valve line to the discharge or high-pressure (liquid) side Schrader valve.

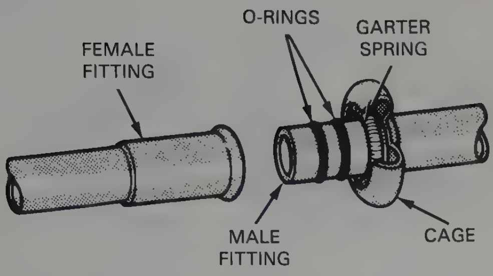
Manifold gauge valves must be OFF (turned fully clockwise) before connecting gauge lines to Schrader valves.

When finished, replace Schrader valve protective caps. Tighten FINGER TIGHT ONLY to prevent damage to sealing surface of valve.

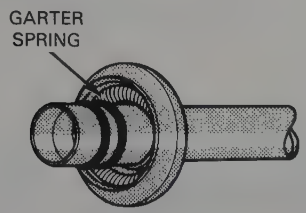
CONNECTING MANIFOLD GAUGE SET TO SYSTEM USING SERVICE FITTINGS OR VALVES WITH HAND-OPERATED SHUTOFF VALVES

The service fitting with a hand shutoff valve permits the gauge lines to be attached to the service fitting gauge connection without using a Schrader valve. A typical shutoff valve service fitting is shown in Fig. 34-32. Note that the valve has three positions.

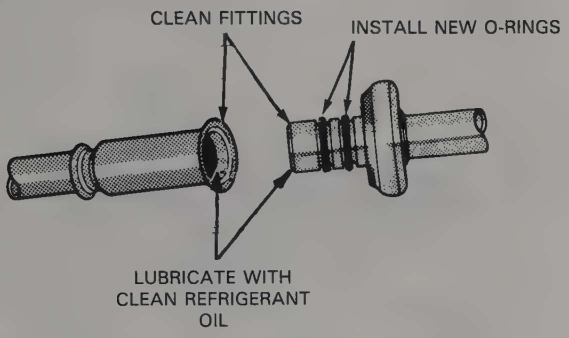
In view A, Fig. 34-32, the valve is shown in the fully closed, clockwise position. This position is also referred to as FRONT-SEATED. This closes the system line to compressor port.


O-RINGS
GARTER SPRING
FEMALE FITTING
MALE FITTING
CAGE

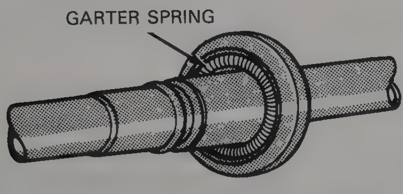
NOTE PARTS OF SPRING LOCK COUPLING.


GARTER SPRING

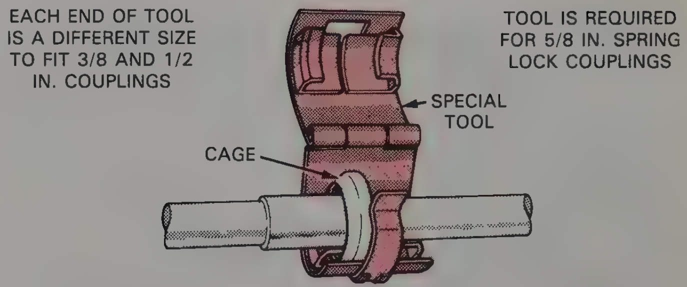
BEFORE CONNECTING, CHECK FOR MISSING OR DAMAGED GARTER SPRING. REMOVE DAMAGED SPRING WITH SMALL HOOKED WIRE. INSTALL NEW SPRING IF DAMAGED OR MISSING.


CLEAN FITTINGS
INSTALL NEW O-RINGS
LUBRICATE WITH CLEAN REFRIGERANT OIL

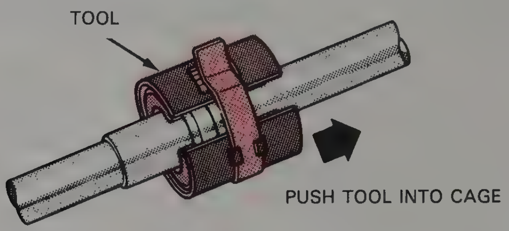
ASSEMBLE FITTING BY PUSHING WITH A SLIGHT TWISTING MOTION.


GARTER SPRING

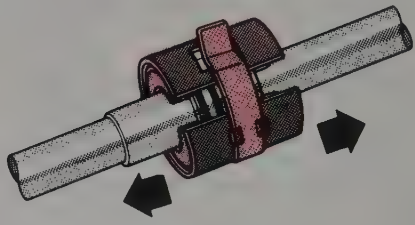
TO ENSURE COUPLING ENGAGEMENT, CHECK TO BE SURE GARTER SPRING IS OVER FLARED END OF FEMALE FITTING.


EACH END OF TOOL IS A DIFFERENT SIZE TO FIT 3/8 AND 1/2 IN. COUPLINGS
TOOL IS REQUIRED FOR 5/8 IN. SPRING LOCK COUPLINGS
SPECIAL TOOL
CAGE

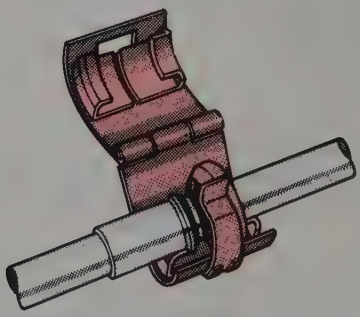
TO DISCONNECT COUPLING, FIT TOOL TO COUPLING SO THAT TOOL CAN ENTER CAGE TO RELEASE GARTER SPRING.


TOOL
PUSH TOOL INTO CAGE

CLOSE TOOL AND PUSH THE TOOL INTO THE CAGE OPENING TO RELEASE THE FEMALE FITTING FROM THE GARTER SPRING.



PULL COUPLING MALE AND FEMALE FITTINGS APART.



REMOVE TOOL FROM DISCONNECTED SPRING LOCK COUPLING.

Fig. 34-29. Inspecting, connecting, and disconnecting a spring lock connector. Note use of special removal tool. (Ford)

In view B, the valve is shown in the fully opened (back-seated) position. This fully counterclockwise position is used for normal operation. Note that the gauge line service port is closed.

When the valve is halfway open (midpositioned), this leaves both ports open so that a gauge may be used to read system pressure. This is also the position for discharging, evacuating, and charging the system, view C, Fig. 34-32.

To attach the gauge lines to the service fitting gauge connections, the valves should be in the fully opened position, B, Fig. 34-32. Remove the gauge line connection cap SLOWLY. When any pressure is exhausted, remove the cap. Attach gauge line. Wear goggles and gloves.

NOTE: MANIFOLD GAUGE VALVES SHOULD BE IN OFF POSITION BEFORE CONNECTING GAUGE LINES TO SERVICE FITTINGS.

Connect the low-pressure gauge line to the compressor low (suction) side. Connect the high-pressure

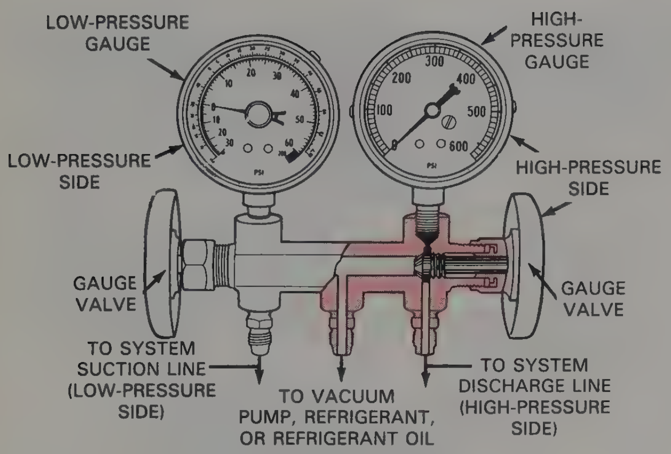

LOW-PRESSURE GAUGE
HIGH-PRESSURE GAUGE
LOW-PRESSURE SIDE
HIGH-PRESSURE SIDE
GAUGE VALVE
GAUGE VALVE
TO SYSTEM SUCTION LINE (LOW-PRESSURE SIDE)
TO VACUUM PUMP, REFRIGERANT, OR REFRIGERANT OIL
TO SYSTEM DISCHARGE LINE (HIGH-PRESSURE SIDE)

Fig. 34-30. Manifold gauge set. (Harrison)

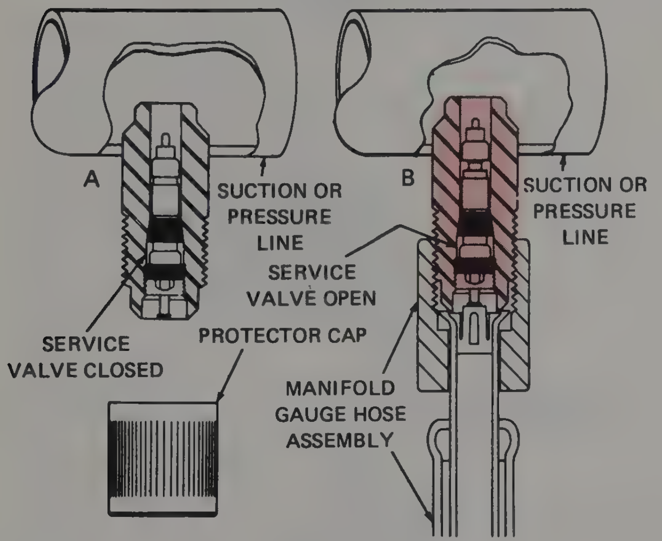

A
B
SUCTION OR PRESSURE LINE
SUCTION OR PRESSURE LINE
SERVICE VALVE OPEN
SERVICE VALVE CLOSED
PROTECTOR CAP
MANIFOLD GAUGE HOSE ASSEMBLY

Fig. 34-31. An air conditioning compressor service valve. A—Typical Schrader valve construction. B—Manifold gauge hose connected to Schrader valve. (Ford)

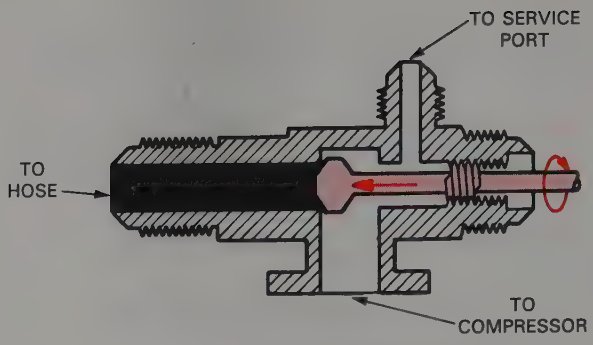
gauge line to the compressor high (discharge) side. Open both service valves halfway, Fig. 34-32.

Instructions for attaching the manifold center connection to the refrigerant container or vacuum pump will be found in the sections dealing with discharging, evacuation, and charging.

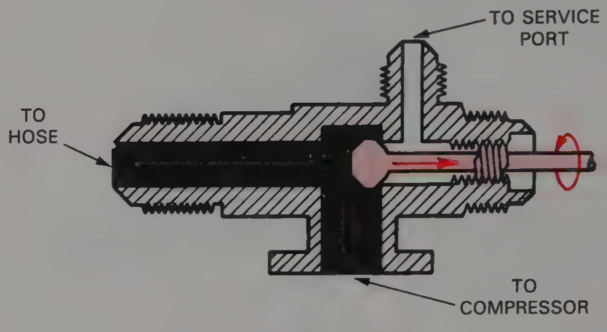
SYSTEM PART REMOVAL — RELATED STEPS

When the refrigeration system must be opened for part removal and replacement, the following steps must be taken—in the order listed:

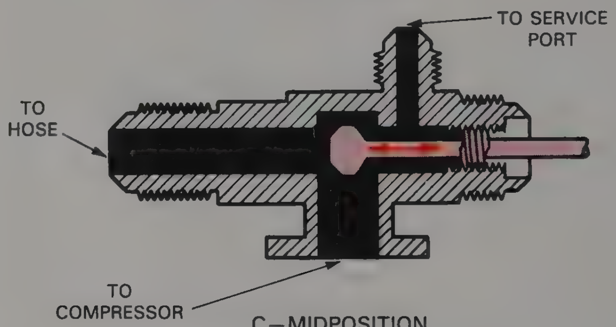
1. Check system for leaks.
2. Discharge system.
3. Remove and replace part.
4. Evacuate system.
5. Charge system.
6. Check for leaks.


TO SERVICE PORT
TO HOSE
TO COMPRESSOR

A—FRONT-SEATED


TO SERVICE PORT
TO HOSE
TO COMPRESSOR

B—BACK-SEATED


TO SERVICE PORT
TO HOSE
TO COMPRESSOR

C—MIDPOSITION

Fig. 34-32. Service fitting hand valve positions. (AMC)

LEAK DETECTORS

A liquid leak detector may be used. The liquid is placed in contact with the joints being checked. Using a strong light, carefully inspect for signs of bubbles or foam which indicate a leak.

A leak detection method that was commonly used for many years employed a torch type tool (Halide torch), Fig. 34-33. The Halide torch flame, whenever it contacts escaping R-12 refrigerant, produces dangerous PHOSGENE GAS. It is strongly recommended that this type tool no longer be used! The efficient and safe electronic leak detector should be used instead. One is pictured in Fig. 34-34.

PREPARING SYSTEM FOR LEAK DETECTION

When a leak is suspected, torque all connections. Never overtighten to try to stop a leak. If a connection leaks when torqued to specifications, disassemble

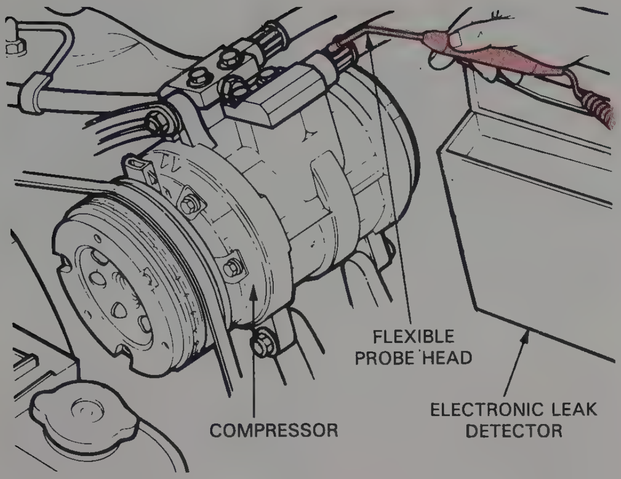


Fig. 34-33. Checking air conditioner line connections with an electronic leak detector. (Ford)

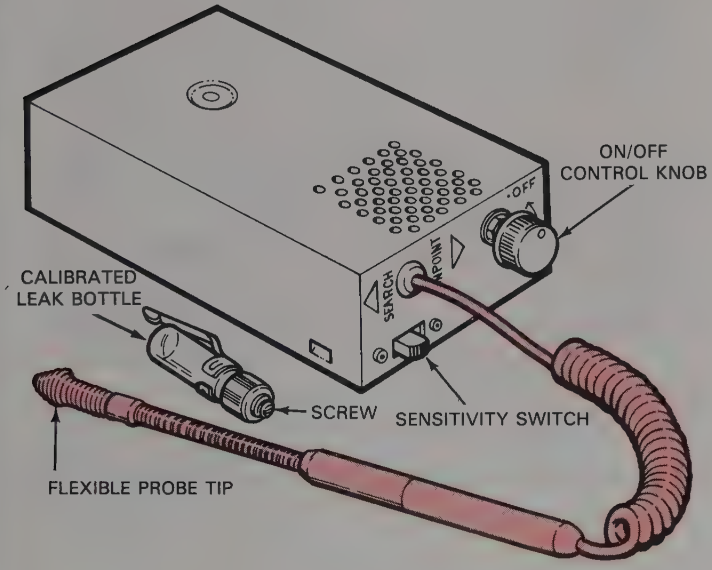


Fig. 34-34. One type of electronic R-12 leak detector. Set up and use exactly as instructed by tool manufacturer. Use this type detector INSTEAD of Halide torch. (Ford)

the joint to determine the cause.

Wipe off joints to remove any excess oil that may have absorbed refrigerant to prevent false readings.

Use a stream of compressed air to clear away any refrigerant vapors. Make certain that the area has sufficient ventilation to keep the air clean. Do not operate the engine while leak testing.

Operate the refrigeration system for a few minutes to build up pressure in the high side. Shut off the engine and test high side for leaks. Never operate a system after it has become discharged.

Wait a few minutes for the pressure to equalize between high and low sides and then test low side of the system for leaks.

A manifold gauge set may be connected into the system and the low side tested under Refrigerant-12 tank pressure. This is higher than the normal low side pressure and will disclose leaks more readily. Detail C, Fig. 34-43, shows the manifold gauge set connected to the compressor service valves. Note that the low side gauge valve is open (counterclockwise position), the high side valve closed (clockwise position). The refrigerant tank valve is open. This charges the low side with tank pressure.

If the system has become discharged, it must be charged (see charging the system) before testing for leaks.

It is good practice to leak test a system before opening the system for repairs. In this manner, any leaks may be repaired at the time the system is open. If the system is not leak tested before opening, after the repairs are made and the system charged, a leak test may disclose leaks that will require reopening the system to correct. By detecting leaks before discharging, harmful air and moisture will not be drawn in when evacuating the system prior to charging.

USING TORCH TYPE LEAK DETECTOR

WARNING: As mentioned earlier, the Halide torch leak detector can produce dangerous Phosgene gas. It is strongly recommended that an ELECTRONIC leak detector be used. In the event that a torch tool MUST be used, observe the following instructions carefully.

Light the torch. When the copper reaction plate is hot (glowing), adjust the flame to about 3/8 in. (9.5 mm) above the reaction plate. The flame should be small (more sensitive to leaks) and an almost colorless, pale blue.

If the flame is yellow, check the search (sampler) hose and the burner tube for obstructions. Check for a clogged orifice.

At times, a dirty reaction plate will cause a yellow flame. After several minutes of burning, the flame should turn pale blue.

If the copper reaction plate is covered with an oxide film, the sensitivity of the flame will be reduced. To correct, lightly scrape the plate with a sharp knife.

When the torch flame is correct, place the end of the search hose near the various joints. Since refrigerant vapor is heavier than air, place the hose at the BOTTOM of the joint.

Hold the hose near the bottom of each joint for several seconds. While the search hose is in position, watch the flame carefully. If a small leak exists, the flame will turn YELLOW-GREEN. A medium size leak will turn the flame BLUE, while a large leak will cause it to turn PURPLE.

Check all connections, joints, and parts. Make sure the surrounding air is not contaminated with refrigerant vapor. Before testing, blow away any vapors with compressed air or a large fan. While testing, the surrounding air should be relatively still.

WARNING: NEVER BREATHE FUMES OR BLACK SMOKE PRODUCED BY TORCH FLAME WHEN SEARCH HOSE IS PLACED NEAR LEAKING JOINT. THE REFRIGERANT, WHEN BURNED BY THE FLAME, FORMS A DANGEROUS GAS (PHOSGENE). KEEP A FIRE EXTINGUISHER AT HAND IN THE EVENT THE TORCH FLAME SHOULD START A FIRE.

USING ELECTRONIC LEAK DETECTOR

When using an electronic leak detector, it is very important to follow the tool manufacturer's instructions EXACTLY. When this is done, the electronic detector is a very sensitive and reliable tool. Many models emit both visual and audible signals to alert the operator to the presence of R-12.

After setting up detector as recommended by the manufacturer, pass the probe tip near the area being checked. In Fig. 34-35, a specialist is checking the compressor area.

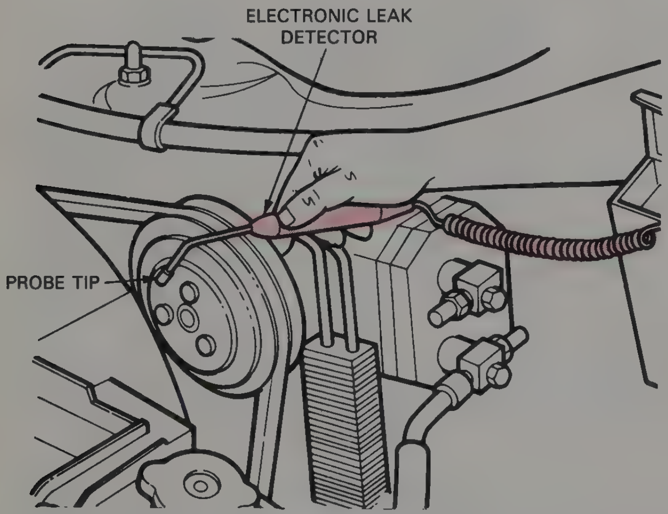

ELECTRONIC LEAK DETECTOR
PROBE TIP

Fig. 34-35. Using electronic leak detector. When probe tip nears an area with a leak, tool will emit a loud signal. (Ford)

Keep the probe close to the suspected leak. Move the probe slowly, around 1 in. (25.4 mm) per second. Circle completely around fittings paying particular attention to the bottom areas. R-12 is heavier than air and tends to settle downward. Study the probe movement recommendations of one maker in Fig. 34-36.

Common leak check points for one system are illustrated in Fig. 34-37.

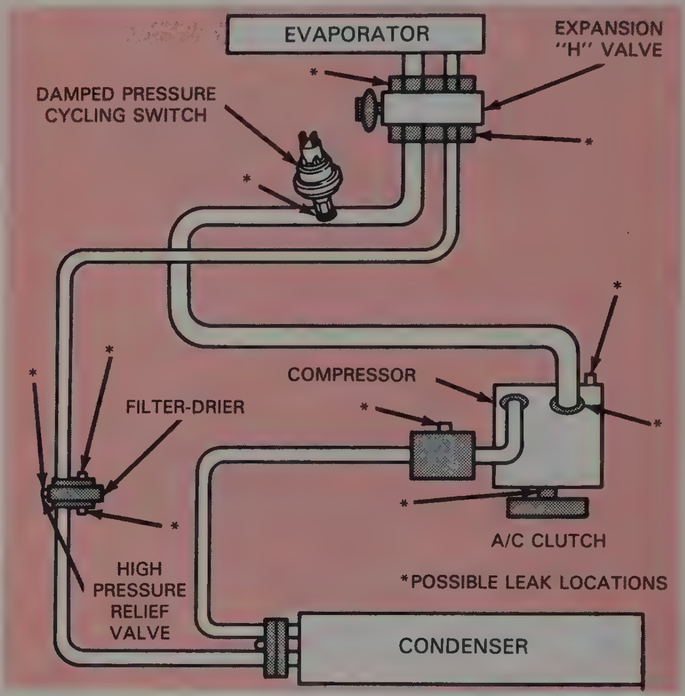

EVAPORATOR
EXPANSION "H" VALVE
DAMPED PRESSURE CYCLING SWITCH
COMPRESSOR
FILTER-DRIER
A/C CLUTCH
HIGH PRESSURE RELIEF VALVE
*POSSIBLE LEAK LOCATIONS
CONDENSER

Fig. 34-37. Typical system areas to check for possible leaks. (Chrysler)

DISCHARGING SYSTEM

There are several commonly recommended procedures for discharging the system.

Some makers advise that the system be discharged

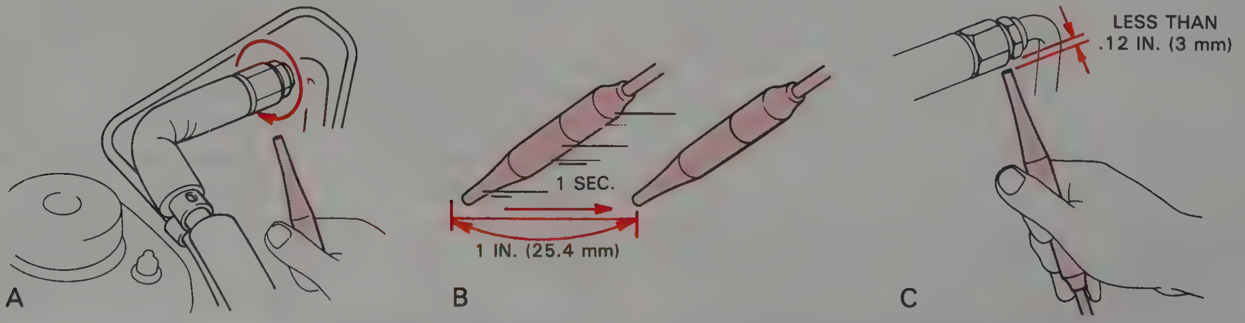

A
1 SEC.
1 IN. (25.4 mm)
B
LESS THAN .12 IN. (3 mm)
C

Fig. 34-36. Electronic leak detector probe tip use as recommended by one maker. A—Move probe completely around suspected leak area. B—Move probe tip slowly, about 1 in. (25.4 mm) per second. C—Keep probe tip close to leak area. (Toyota)

by opening the low side to atmosphere. Others suggest opening the high side. some advise opening both sides. The recommended rate of discharge will also vary. A fast discharge will pull out a certain amount of refrigerant oil while the slow method will allow R-12 to escape without much oil removal.

Always check system for leaks before discharging. The system must be discharged (refrigerant removed) prior to the replacement of any part of the refrigeration group. The only exception to this would be the compressor WHEN IT IS EQUIPPED WITH HAND-OPERATED SERVICE VALVES. When the service valves on the compressor are fully closed, clockwise, A, Fig. 34-32, the compressor will be isolated (shut off) from the rest of the system. Once the compressor is isolated, crack open (open a very small amount) the gauge fitting cap to relieve the pressure in the compressor. The compressor may then be removed.

A couple of common techniques will be covered to illustrate general procedures. Always follow recommendations of the maker for the exact system at hand. Do not operate the engine during discharge operation. WEAR GOGGLES AND GLOVES.

GAUGE SET HIGH SIDE DISCHARGING — HAND VALVE SERVICE FITTINGS

To discharge the system, connect the manifold gauge set to the gauge fittings. Place the end of the hose from the manifold CENTER connection into the service area exhaust outlet.

When connecting the manifold gauge set into the system, always close both manifold valves before connecting. Connect the low-pressure compound gauge manifold outlet to the system low or suction side (gauge fitting may be on suction side of compressor). Connect the high-pressure gauge manifold outlet to the high or discharge side of the compressor.

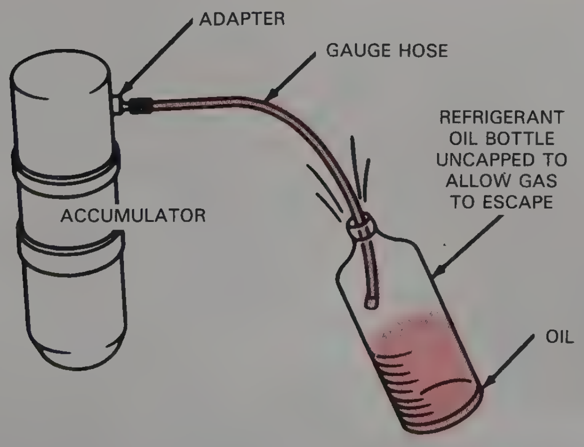


Fig. 34-38. Discharging a C.C.O.T. system by using a gauge hose connected to low-side accumulator by means of a Schrader valve. Note bottle to retain oil for measuring. Be careful. Bottle should be placed in or near an exhaust vent to remove R-12 vapor. (Chevrolet)

The service fitting hand valves must be fully closed before removing gauge fitting cap.

OPEN the manifold high-pressure gauge valve. Keep the low-pressure (compound gauge) valve CLOSED.

CRACK (open a very small amount) the service valve on the compressor discharge side (side leading to condenser). Allow the refrigerant to SLOWLY escape through the center outlet hose. HOSE SHOULD BE IN SERVICE AREA EXHAUST SYSTEM OUTLET, A, Fig. 34-43. Rapid discharging will draw compressor oil from the system.

Some makers recommend discharging into a container so that any possible oil loss can be checked. Lost oil should be replaced with FRESH oil.

With this same setup, some makers advise opening both HIGH and LOW side service valves a small amount.

GAUGE SET HIGH SIDE DISCHARGING — SCHRADER VALVE SERVICE FITTINGS

Connect gauge set as previously directed. BOTH VALVES MUST BE CLOSED.

CRACK the manifold high-pressure gauge valve. Allow refrigerant to SLOWLY escape out the center connection hose into the service area exhaust outlet.

When the high-pressure gauge reads less than 100 psi (690 kPa), crack the low-pressure gauge valve. Discharge until all pressure is removed. Discharge into a container to check oil loss if recommended.

LOW SIDE DISCHARGING WITHOUT GAUGE SET — C.C.O.T. SYSTEM

The C.C.O.T. (cycling clutch orifice tube) system can be discharged quite simply by using a gauge hose. Place one end of the hose in a suitable container (a coffee can or bottle with slits in a plastic cover is fine). Place container near a shop vent. Remove Schrader valve cap on accumulator low side. Using proper adapter, attach hose. See Fig. 34-38.

Slowly tighten hose adapter onto Schrader valve until R-12 begins to flow into the container. Allow to slowly discharge until system is empty.

Check high side fitting carefully for pressure. There should be none. If there is, use same technique as above to discharge. After discharging high side, determine what caused restriction that maintained high side pressure.

Following COMPLETE discharge, carefully measure amount of oil collected in discharge bottle. Discard this old oil. When ready, the SAME amount of NEW oil will have to be returned to the system.

OIL REMOVAL DURING DISCHARGE OPERATION

Keep in mind that some recommended procedures call for relatively FAST discharge so that considerable oil will be drawn out with the R-12. It is very important that the system be discharged into a container so that ALL oil removed can be measured. Remember that the same amount of FRESH oil will have to be returned to the system.

EVACUATING SYSTEM

Evacuating involves attaching a vacuum pump to the system to remove air and moisture.

Attach the manifold gauge set. Both gauge valves must be OFF. Attach a vacuum pump and a tank of R-12 to the manifold gauge set center connection. REFRIGERANT-12 TANK VALVE MUST BE TIGHTLY CLOSED.

Fig. 34-39 illustrates a hookup for evacuating a system. The same setup will be used for charging. Where hand-operated service valves are used instead of Schrader valves, they must be in the "cracked" position.

Instead of having the manifold gauge set, compressor, refrigerant tank, and lines all separated so everything must be hooked up each time, many garages use a CHARGING STATION. This contains the necessary parts and they are all connected. The parts are attached to a roll cart, thus making a handy unit. See Fig. 34-40.

Open the high-pressure manifold gauge valve slowly to relieve any pressure buildup (system should have already been discharged). Close the high-pressure valve.

Start the vacuum pump. If there is a manual valve in the vacuum line, open it.

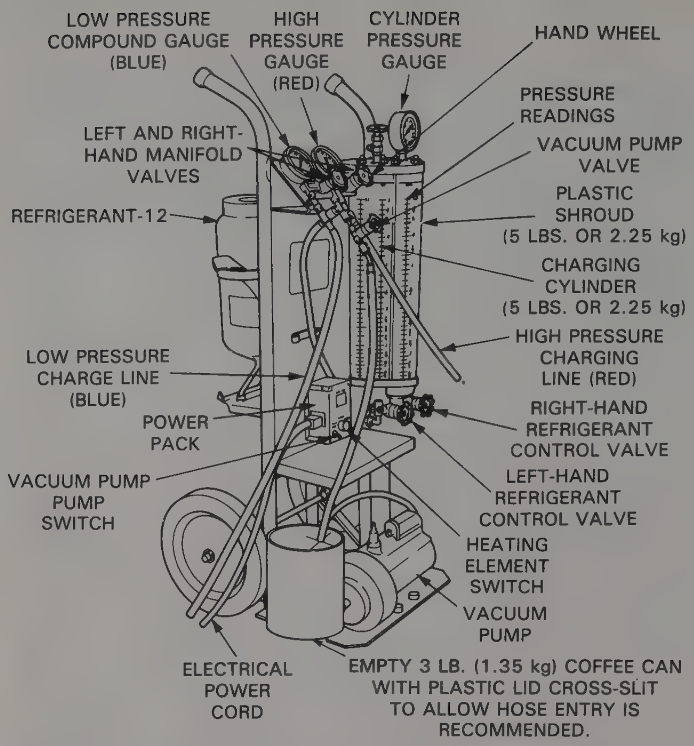

LOW PRESSURE COMPOUND GAUGE (BLUE)
HIGH PRESSURE GAUGE (RED)
CYLINDER PRESSURE GAUGE
HAND WHEEL
PRESSURE READINGS
LEFT AND RIGHT-HAND MANIFOLD VALVES
VACUUM PUMP VALVE
REFRIGERANT-12
PLASTIC SHROUD (5 LBS. OR 2.25 kg)
CHARGING CYLINDER (5 LBS. OR 2.25 kg)
HIGH PRESSURE CHARGING LINE (RED)
LOW PRESSURE CHARGE LINE (BLUE)
RIGHT-HAND REFRIGERANT CONTROL VALVE
POWER PACK
VACUUM PUMP PUMP SWITCH
LEFT-HAND REFRIGERANT CONTROL VALVE
HEATING ELEMENT SWITCH
VACUUM PUMP
ELECTRICAL POWER CORD
EMPTY 3 LB. (1.35 kg) COFFEE CAN WITH PLASTIC LID CROSS-SLIT TO ALLOW HOSE ENTRY IS RECOMMENDED.

Fig. 34-40. Typical charging station. It may be used for discharging, evacuation, and charging. (G.M.C.)

Slowly open both the high and low-pressure manifold gauge valves. Open vacuum pump shutoff valve. Open valve slowly to prevent oil from being drawn out of the pump.

Run the vacuum pump until the low-pressure gauge (vacuum portion) indicates 28 in. (711 mm) of vacuum at sea level.

NOTE: The vacuum pump, in proper condition, should draw a vacuum of 28 in. (711 mm) at sea level. Subtract 1 in. (25.4 mm) for every thousand feet (304 M) of elevation. For example: At 5,000 feet, the pump

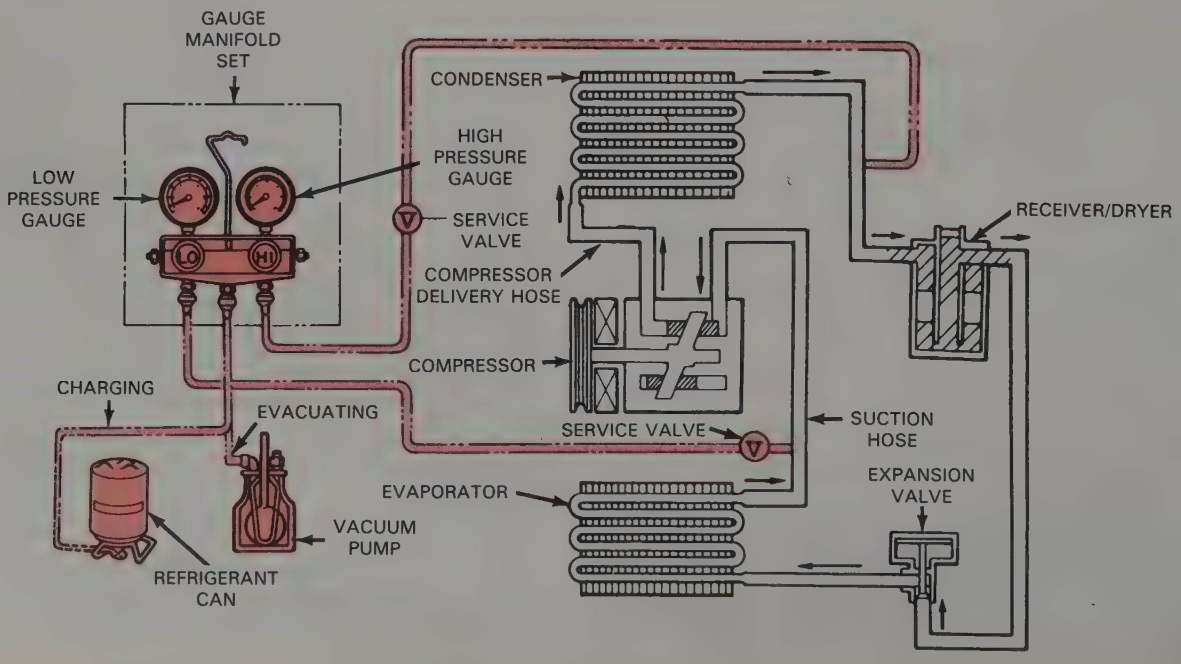

GAUGE MANIFOLD SET
CONDENSER
LOW PRESSURE GAUGE
HIGH PRESSURE GAUGE
LO
HI
SERVICE VALVE
RECEIVER/DRYER
COMPRESSOR DELIVERY HOSE
COMPRESSOR
CHARGING
EVACUATING
SERVICE VALVE
SUCTION HOSE
EXPANSION VALVE
EVAPORATOR
VACUUM PUMP
REFRIGERANT CAN

Fig. 34-39. Setup for evacuating and charging system. (Geo)

should draw 23 in. (28 in. minus 5 in.).

IF THE VACUUM CANNOT BE DRAWN TO AT LEAST 26 in. (660 mm) at sea level, either the pump is defective or there is a leak in the system or hookup lines.

When the gauge reads 26-28 in. of vacuum, run the pump for an additional 10 or 15 min. Then shut off both the high and low-pressure gauges. Shut off valve in vacuum line and stop vacuum pump. System should hold vacuum with no more than a 2 in. (51 mm) drop in five minutes.

ADD REFRIGERANT TO SYSTEM FOR LEAK TESTING

After shutting off the vacuum pump at the end of 10 or 15 min., put a partial charge into the system for leak testing.

If a charging station is being used, meter out the recommended amount of liquid refrigerant into the charging cylinder (amount recommended by manufacturer for a partial charge for leak test purposes).

Slowly open the high-pressure gauge valve. Open the charging cylinder top valve and allow the specified amount of refrigerant to enter the system. Close the high-pressure gauge valve. Close the charging cylinder top valve. When the partial charge has entered the system, leak test as recommended earlier.

REMOVE PARTIAL CHARGE

After checking for leaks, discharge the system to remove the partial charge. See section on discharging the system.

MAKE FINAL SYSTEM EVACUATION

Following discharge of the partial charge, evacuate the system again. Operate the vacuum pump for 10 min. after the gauge shows a vacuum of from 26-28 in.

Shut off both gauge valves. Shut off pump valve and stop pump. The system should be leak free, free of air and moisture, and contain a vacuum. The system is ready to be charged.

CHARGING SYSTEM

There are three possible R-12 supply sources used for system charging: charging station, drum, or disposable can. All work equally well. Be certain to follow all maker recommendations for charging method used. Above all, OBSERVE ALL SAFETY RULES REGARDING STORAGE, HANDLING, AND USE OF R-12. WEAR GOGGLES AND GLOVES!

There are several recommended charging techniques. One method charges the LOW side with R-12 vapor, engine running. Another charges the HIGH side with R-12 liquid, engine off. As with discharge technique, always follow exact directions for method employed. Following are a couple of typical methods. Remember, when charging into the LOW side (on some systems) with the engine operating, R-12 VAPOR must be used as liquid R-12 may damage the compressor.

HIGH SIDE SYSTEM CHARGING — USING A CHARGING STATION

Before charging, the system should have been evacuated, filled with a partial charge, leak tested, and evacuated again.

If a charging station such as shown in Fig. 34-40 is being used, fill the charging cylinder with the amount of liquid refrigerant specified for a full charge. The amount varies according to the system but will often range from around 2 1/4 to 4 lbs. (1.1 to 1.8 kg).

With the charging station charge cylinder filled the specified amount, engine OFF, open the high-pressure gauge fully. The low-pressure gauge valve must be closed. Open valve at top of the charging cylinder and allow refrigerant to flow into the high-pressure side of the system.

When refrigerant stops flowing into system, shut off the high-pressure gauge valve. Start the car engine and operate at 1500 rpm. Set air conditioner controls for maximum cold and turn system on.

Open the low-pressure gauge valve so the suction side of the system will draw in the remaining refrigerant.

When all refrigerant has entered the system, close all valves, shut off engine, and disconnect charging station from the system. If the charging station lines are attached to service fittings with hand valves, fully open them to seal off the gauge line connection. Replace connection caps. Operate system and check for proper operation.

Fig. 34-41 shows a system being charged.

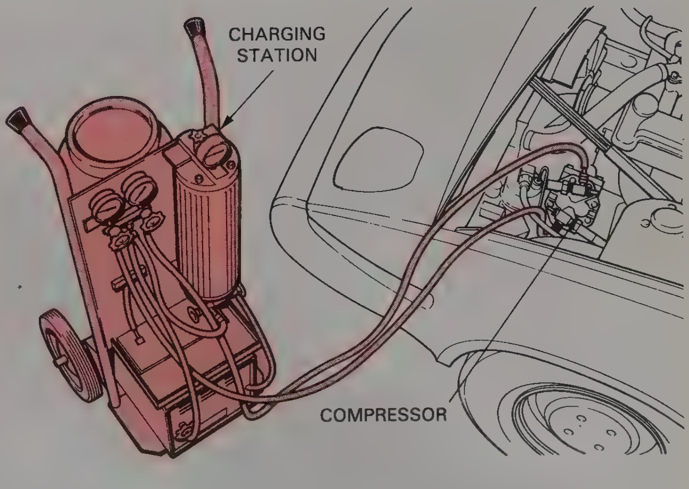


Fig. 34-41. Using charging station to charge refrigeration system. (British-Leyland)

HIGH SIDE SYSTEM CHARGING — WEIGHING METHOD

With engine off, connect the manifold gauge set to the system. Evacuate, partial charge, leak test, and evacuate the system. Gauge valves should both be closed.

Connect refrigerant tank to manifold gauge center connection. With both valves off, crack refrigerant tank valve open. Crack tank hose connection at manifold for a few seconds to allow the refrigerant to purge (blow out) air from the hose. Tighten hose connection. Open refrigerant tank valve fully.

Place refrigerant tank in a pail of warm water. Water temperature must not exceed 125°F (52°C).

Place pail and tank on an ACCURATE scale. Note EXACT weight of assembly. Look at Fig. 34-42.

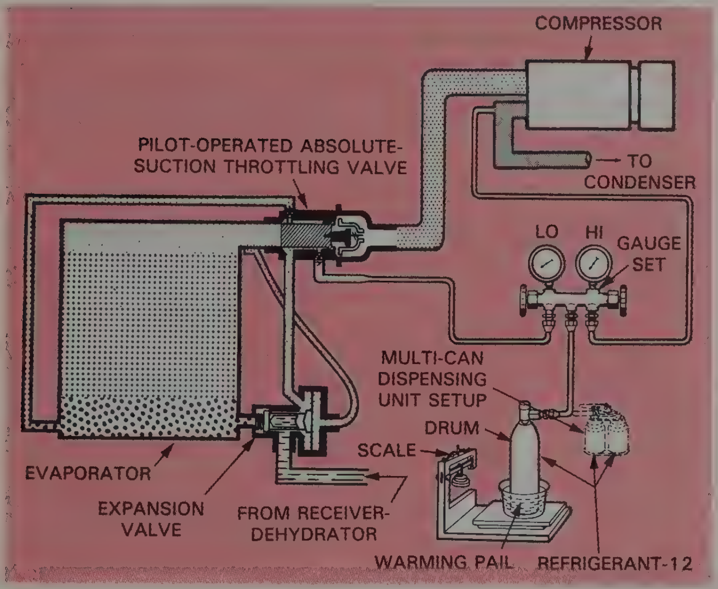

COMPRESSOR
PILOT-OPERATED ABSOLUTE-SUCTION THROTTLING VALVE
TO CONDENSER
LO
HI
GAUGE SET
MULTI-CAN DISPENSING UNIT SETUP
DRUM
SCALE
EVAPORATOR
EXPANSION VALVE
FROM RECEIVER-DEHYDRATOR
WARMING PAIL
REFRIGERANT-12

Fig. 34-42. Setup used for charging system with refrigerant tank and warming pail on a scale. (Oldsmobile)

Open the HIGH-PRESSURE gauge valve so a charge of LIQUID refrigerant will enter the high-pressure side of the system. LOW-PRESSURE valve must be closed. Liquid refrigerant may be obtained by drawing from the bottom of the tank or by turning the tank upside-down. This is shown in D, Fig. 34-43.

Allow the liquid refrigerant to flow into the system until the desired amount (in lbs. or kg) has entered. Check scale.

If sufficient liquid refrigerant will not enter the system, close the high-pressure gauge valve.

Turn the tank right side up or draw from the top of the tank so that refrigerant VAPOR will be available. See C, Fig. 34-43.

Start the car engine and operate at 1500 rpm. Turn air conditioner on and set to maximum cold.

Open the LOW-PRESSURE gauge valve and allow refrigerant vapor to flow into the low side of the system until the required charge has entered.

Shut off low-pressure gauge valve. Stop engine. Shut off refrigerant tank. Disconnect charge setup from system.

Operate system and check for proper operation.

IMPORTANT: UNLESS SPECIFICALLY RECOMMENDED (SUCH AS WITH SOME C.C.O.T. SYSTEMS), NEVER ALLOW LIQUID REFRIGERANT TO ENTER THE LOW (SUCTION) SIDE OF THE SYSTEM. CHARGE THE HIGH SIDE WITH LIQUID. CHARGE THE LOW SIDE WITH VAPOR.

Remember that when R-12 container is UPRIGHT, it will discharge VAPOR. When container is UPSIDE-DOWN or on its side, it will discharge LIQUID R-12.

LOW SIDE CHARGING C.C.O.T. SYSTEM — USING DISPOSABLE CANS

Attach the LOW pressure gauge to the accumulator (low pressure side of system). The high pressure gauge

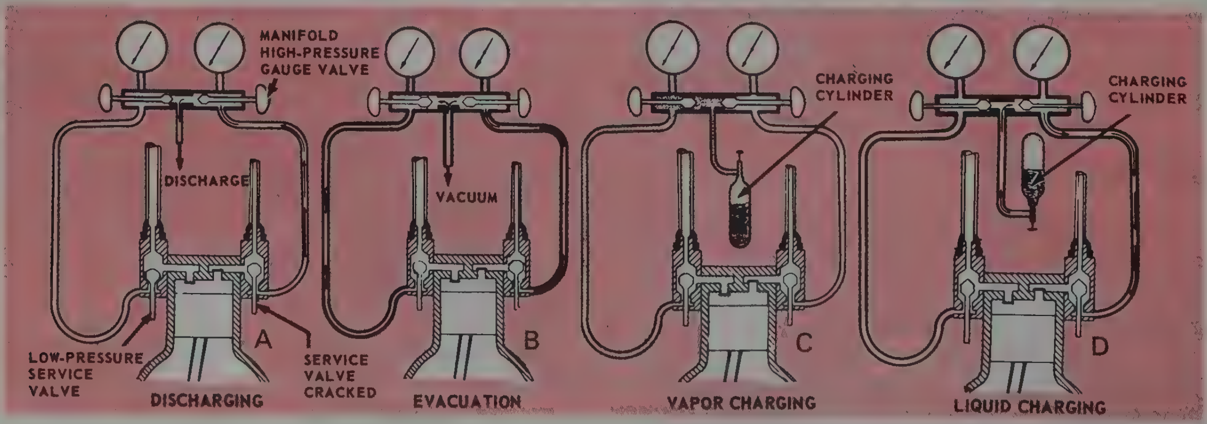

MANIFOLD HIGH-PRESSURE GAUGE VALVE
DISCHARGE
LOW-PRESSURE SERVICE VALVE
A
SERVICE VALVE CRACKED
DISCHARGING
VACUUM
B
EVACUATION
CHARGING CYLINDER
C
VAPOR CHARGING
CHARGING CYLINDER
D
LIQUID CHARGING

Fig. 34-43. Gauge valve and service fitting hand valve positions for: A—Discharging system. B—System evacuation. C—Charging system LOW-PRESSURE SIDE with refrigerant VAPOR. D—Charging HIGH-PRESSURE SIDE with LIQUID refrigerant. Note that refrigerant tank, in D, is upside-down to draw liquid refrigerant. (American Motors)

should be connected to the vacuum pump. Attach gauge set center hose to the one pound can dispenser unit. Fig. 34-44 illustrates a typical setup.

Following proper system evacuation, CLOSE high side gauge valve and leave closed. With air conditioning control OFF, start engine and idle at normal hot idle speed.

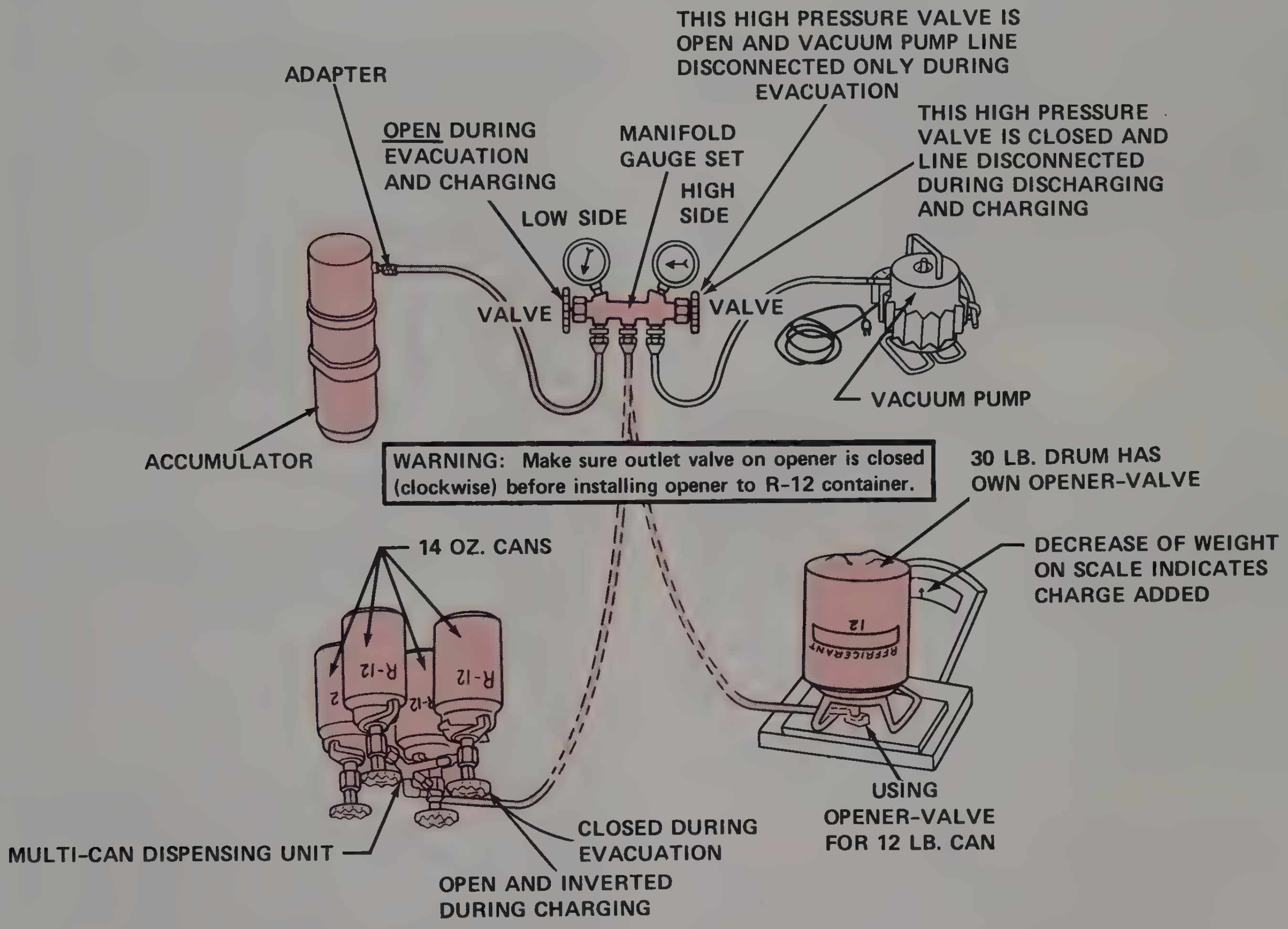

THIS HIGH PRESSURE VALVE IS OPEN AND VACUUM PUMP LINE DISCONNECTED ONLY DURING EVACUATION
ADAPTER
OPEN DURING EVACUATION AND CHARGING
MANIFOLD GAUGE SET
THIS HIGH PRESSURE VALVE IS CLOSED AND LINE DISCONNECTED DURING DISCHARGING AND CHARGING
HIGH SIDE
LOW SIDE
VALVE
VALVE
VACUUM PUMP
ACCUMULATOR
WARNING: Make sure outlet valve on opener is closed (clockwise) before installing opener to R-12 container.
30 LB. DRUM HAS OWN OPENER-VALVE
14 OZ. CANS
DECREASE OF WEIGHT ON SCALE INDICATES CHARGE ADDED
R-12
R-12
R-12
12
12
REFRIGERANT
USING OPENER-VALVE FOR 12 LB. CAN
CLOSED DURING EVACUATION
MULTI-CAN DISPENSING UNIT
OPEN AND INVERTED DURING CHARGING

Fig. 34-44. Charging a C.C.O.T. system using one-pound containers or a drum. Note that in this specific setup, the cans are inverted (upside-down). This will feed liquid R-12 into system low-side through the accumulator. Many systems require that the cans be right-side-up so that R-12 VAPOR will be fed into system low-side. NEVER CONNECT THESE SMALL CONTAINERS TO SYSTEM HIGH SIDE — THEY COULD EXPLODE! (Chevrolet)

Invert cans (this will allow LIQUID R-12 to flow). Open one can and allow it to flow into system via accumulator fitting. When one pound has entered, turn air conditioning control to ON. continue idling engine until recommended charge has entered system.

Shut off R-12 dispensing unit and continue engine operation for around one-half minute. This will clear lines and gauges.

Before shutting off engine, remove low side hose adapter from accumulator service fitting. When removing, unscrew quickly to prevent excessive loss of R-12.

NOTE: DO NOT REMOVE GAUGE LINE FROM THE ADAPTER UNTIL ADAPTER IS REMOVED FROM SERVICE FITTING. NEVER REMOVE CHARGE HOSE AT GAUGE SET UNTIL FIRST REMOVED FROM SERVICE FITTING AS THIS WOULD RESULT IN RAPID, COMPLETE, AND UNCONTROLLED LOSS OF THE ENTIRE R-12 CHARGE!

Cap service fitting and shut engine off. Remember to check system for leaks and for proper operation.

When using the one pound cans, NEVER connect them to the system high side as they can explode from system pressure backfeeding into them.

Open one can and when it has entered the system, shut off the valve for that can. Repeat, using a second can. Continue until the correct number of pounds of refrigerant have entered the system.

If a one-half pound is called for, open a can valve. When the frost line on the outside of the can reaches the halfway mark, shut off the valve.

The cans are used just as if they were regular refrigerant tanks. Cautions pertaining to tanks also apply to cans.

SYSTEM LUBRICATION

A specific amount (varies with system size) of special refrigerant oil, such as 500 SUS viscosity, is placed in the system when assembled at the factory. This is to provide lubrication for the compressor.

In that Refrigerant-12 has a strong affinity (attraction) for this oil, a certain amount of oil is circulated throughout the system. The remainder stays in the compressor.

This initial amount of oil is all that the system needs. It will remain in the system until a leak develops or the system is opened for part replacement.

If the system is functioning properly and there are no leaks, the oil supply is known to be adequate.

OIL LOSS

Oil can be lost by careless discharging (discharging too fast), a leak in the system, or when replacing a part.

When the evaporator, for instance, is replaced, a certain amount of the system's oil supply would be in the evaporator when removed. When replacing with a new evaporator, add the specified amount of replacement oil directly into the evaporator before installation. This will insure the correct amount of oil is in the system.

When an evaporator, receiver, condenser, or compressor is replaced, a specific amount of oil should be added to replenish that lost by the exchange.

The expansion valve, suction throttling valve, and lines may be replaced WITHOUT adding oil.

CHECKING SYSTEM OIL LEVEL

If the system has been leaking and an oil film is evident, the oil level should be checked.

Some double-acting, six cylinder compressors have a small oil level valve near the bottom. If so equipped, run the system for 15 min. at maximum cooling.

Shut off system and crack valve cap open. If oil drips out, tighten cap. Wait a few moments and reopen. If oil comes out in a steady stream, sufficient oil is present. If refrigerant vapor hisses out, the oil level is low and must be corrected.

Many of the double-acting compressors (Fig. 34-15) must be removed to check the oil level. Run system for 15 min. at maximum cooling (unless too much oil has escaped from system). Shut off. Discharge system and remove compressor. Cap lines.

With the compressor in a horizontal position (oil sump down), drain the oil into a clean can. Carefully measure the oil removed to determine the EXACT number of fluid ounces.

Examine the condition of the oil. If chips, water, sludge, or other debris is present, the system should be flushed with refrigerant or dry nitrogen. Following installation of a new or rebuilt compressor, replace the receiver-dehydrator. Discard the drained oil regardless of condition.

If the system is flushed, the new compressor must contain the full amount of oil recommended for the system.

REMEMBER THAT THE SYSTEM MUST HAVE AN EXACT AMOUNT OF OIL

It is essential that oil, in the proper amounts, be added when system parts are replaced. By comparing the amount that was drained from the compressor with the amount that under normal condition SHOULD be in the compressor, it is possible to add oil in quantities that will maintain the correct amount in the system.

Too little oil will ruin the compressor, too much will reduce system efficiency. Consult the manufacturer's manual for recommended amounts of replacement oil.

CHECKING COMPRESSOR OIL LEVEL

A number of compressors have provisions for checking the oil level. On a two cylinder, such as pictured in Fig. 34-45, proceed as follows:

Operate the system at maximum cooling, 1500 rpm for 15 min. Shut engine and system off.

Isolate the compressor from the system by fully closing both service fitting hand valves.

With the valves closed, loosen the high-pressure gauge fitting cap. Let the gas escape until the pressure is removed from within the compressor. The cap must be loosened slowly and only a small amount.

Remove the oil filler plug. Pass a clean flattened 1/8 in. (3.18 mm) steel rod through the filler hole and down to the bottom of the sump. It may be necessary to turn

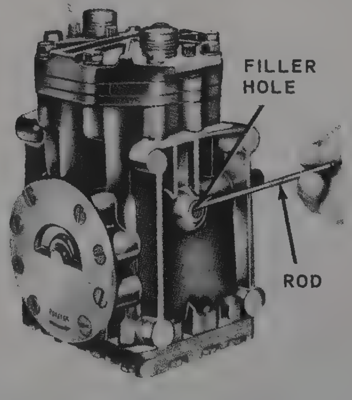


Fig. 34-45. With compressor isolated, oil level may be checked by passing steel rod through oil filler hole. (Ford)

the crankshaft a small amount to clear the rod. Withdraw the rod and measure the oil depth. Compare with manufacturer's specifications, Fig. 34-45.

Add or remove oil as needed. Replace filler plug. The O-ring must be in good condition. Evacuate compressor by drawing a vacuum on the high-pressure fitting gauge connection. Shut the vacuum pump line valve and fully open both service fitting hand valves. Remove vacuum line and replace gauge connection cap. Replace caps on both valve stems.

Fig. 34-46 shows a dipstick used on one type of radial compressor.

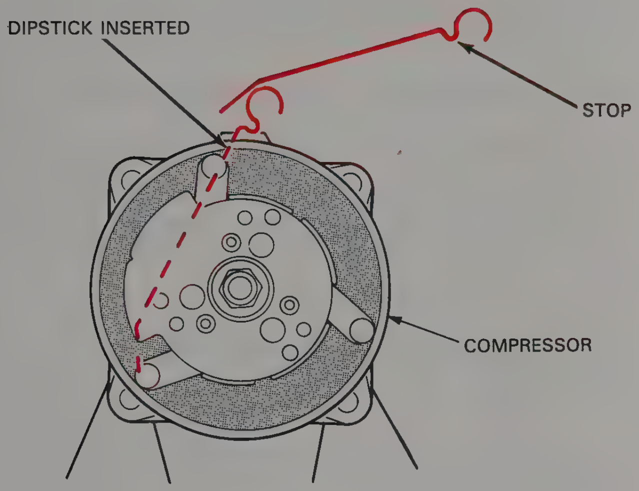


Fig. 34-46. Checking oil level in a compressor. (Chrysler)

ADDING OIL TO SYSTEM BY INJECTION

Some systems may have oil added (when compressor oil level indicates need) without discharging the system, by using a special injection device.

The injector is connected to the low-pressure gauge manifold connection, Fig. 34-47. The center manifold connection is capped. The gauge set is connected into the system. The lines, gauges, and injector connections are purged. The system is then operated with the gauge valves open and with the service fitting hand valves opened halfway. This will draw the oil into the suction side of the compressor.

Following oil injection, recheck level in compressor. Fig. 34-47 shows one setup used for oil injection.

FLUSHING

When flushing parts to remove contamination, wear goggles, gloves, and protective clothing. Use a recommended flushing agent (R-11 is often specified). Flushing should be done outside, or in a controlled ventilation area built for this type of service. Fig. 34-48 illustrates a setup for flushing the condenser.

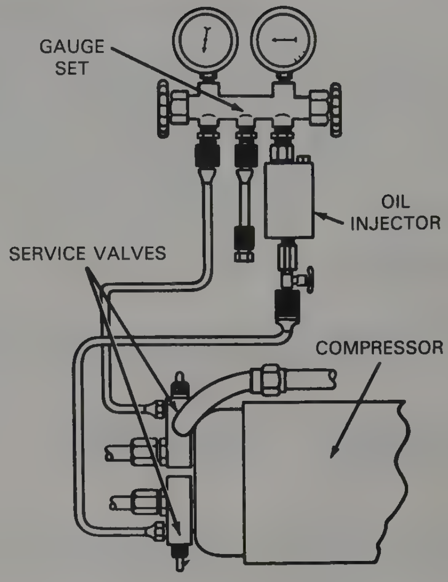


Fig. 34-47. Adding oil to system by injection. (Chevrolet)

PERFORMANCE COMPLAINTS — MAKE SIMPLE CHECKS FIRST

When the owner complains of poor air conditioning performance, DO NOT START ON AN ELABORATE, FULL-SCALE SYSTEM ANALYSIS. MAKE A FEW SIMPLE CHECKS FIRST. THESE QUICK CHECKS MAY UNMASK THE TROUBLE.

CHECK NUMBER 1 — PROPER SYSTEM OPERATION

Ask the owner to operate the system. Observe how he or she sets the controls. You will discover that

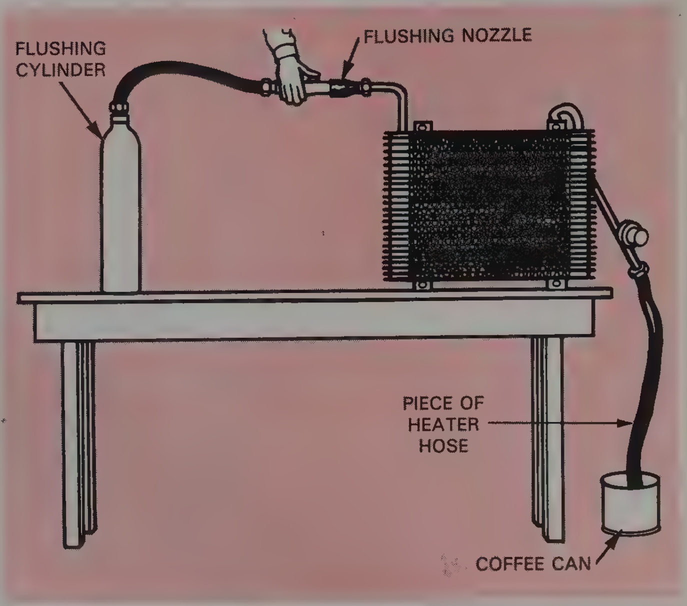


Fig. 34-48. One setup for flushing a condenser. Use a recommended flushing agent. (GM)

occasionally the driver either sets the controls wrong or operates the system with one or more windows open. Instruct the driver as to the proper operating technique. Explain that cooling efficiency will vary with ambient (moving) air temperature and humidity. On a hot or humid day, the system may fail to cool the car to the point to which it is normally capable.

CHECK NUMBER 2 — DRIVE BELT

Inspect the compressor drive belt for looseness, excessive wear, or breakage. Adjust or repair as needed.

CHECK NUMBER 3 — COMPRESSOR MAGNETIC CLUTCH

Check the operation of the compressor magnetic clutch to make certain the compressor is being driven.

CHECK NUMBER 4 — SIGHT GLASS

Start the system and operate for at least 5 minutes with controls set for maximum cooling. Engine speed should be around 1500 rpm.

Examine the refrigerant flow through the sight glass. IF THE AMBIENT AIR TEMPERATURE IS ABOVE 70-75°F (21-24°C), there usually should not be any foam or bubbles visible. Bubbles, when the temperature is below 70°F (21°C), are normal.

If bubbles or foam show in the glass, the system may be low on refrigerant. Exceptionally high temperatures can occasionally cause the appearance of foam or bubbles.

When the system is empty, no foam or bubbles will be visible. When the system is empty, however, the sight glass will have an oily look and will not be as clear as it would be with the system charged.

If loss of refrigerant is suspected, check for leaks (see leak detection earlier in chapter). Fig. 34-49 shows a chart, used by one maker, with various sight glass conditions, their meanings, and causes.

CHECK NUMBER 5 — INSPECT SYSTEM LINES

Examine hoses and lines to make certain they are not kinked or flattened. Restrictions will often cause cold or frosty spots just beyond the point of restriction.

CHECK NUMBER 6 — AIRFLOW SYSTEM

Inspect blower for proper operation. Check operation of air blending doors (mixes heater air with evaporator air in varying proportions). The air system should be free of obstructions and leaks. Evaporator drain must be open.

CHECK NUMBER 7 — CONDENSER AND RADIATOR

Check the front and rear surfaces of both the radiator and condenser for signs of clogging from bugs, dirt, and other debris. Remove any material that may im-

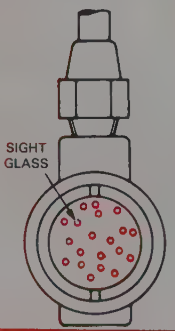
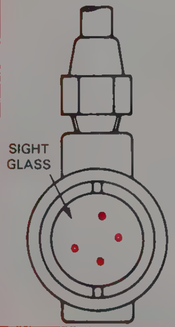
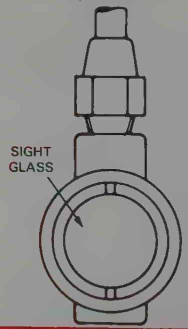
Amount of refrigerant Check item	Almost no refrigerant	Insufficient	Suitable	Too much refrigerant
Temperature of high pressure and low pressure lines.	Almost no difference between high pressure and low pressure side temperature.	High pressure side is warm and low pressure side is fairly cold.	High pressure side is hot and low pressure side is cold.	High pressure side is abnormally hot.
State in sight glass.	Bubbles flow continuously. **Bubbles will disappear and something like mist will flow when refrigerant is nearly gone.** 	The bubbles are seen at intervals of 1 - 2 seconds. 	Almost transparent. Bubbles may appear when engine speed is raised and lowered. **No clear difference exists between these two conditions.** 	No bubbles can be seen.
Pressure of system.	High pressure side is abnormally low.	Both pressure on high and low pressure sides are slightly low.	Both pressures on high and low pressure sides are normal.	Both pressures on high and low pressure sides are abnormally high.
Repair.	**Stop compressor immediately** and conduct an overall check.	Check for gas leakage, repair as required, replenish and charge system.		Discharge refrigerant from service valve of low pressure side.

Fig. 34-49. Typical sight glass conditions and general indications. (Nissan)

pede airflow. The use of bug screens mounted in front of the radiator and condenser can cause problems.

PERFORMANCE TESTING

It is sometimes difficult to determine just how well the system is functioning by merely depending upon the driver's opinion (based on physical reaction to temperature inside car). As mentioned, temperature and humidity affect system efficiency.

To gain a true picture of system efficiency, it is essential that it be performance tested. Performance testing generally involves checking system operating pressures (low and high side), and the temperature of the air being discharged into the car.

The pressure and temperature readings are then related to ambient air temperature and relative humidity to determine system efficiency under exact operating conditions. Test techniques and specifications vary with the different makes and models. Follow manufacturer's specifications.

SYSTEM SERVICE FOLLOWING COLLISION

When a car has been involved in an accident that could have damaged the refrigeration system, the system should be checked as soon as possible.

If damage is apparent, disengage compressor clutch energizing wire before the car is operated. Replace condenser if damaged. Do not attempt repair by welding, soldering, or other means. Replace damaged lines.

If the system was "open" (damaged to point refrigerant was discharged) for some time, replace the receiver-dehydrator. Replace receiver-dehydrator if damaged. Examine compressor and compressor clutch-pulley for damage. Replace other parts as needed.

COMPRESSOR OVERHAUL

When overhauling a compressor, follow maker's instructions for exact unit being worked upon. Use of a well designed holding fixture will facilitate the work.

Clean thoroughly. Inspect all parts, bearings, and sealing surfaces. Replace worn or damaged components. Use new seals and gaskets. Lubricate selected parts with clean, fresh refrigerant oil of correct type and viscosity.

Always use proper tools to insure correct disassembly and assembly without part distortion or seal surface damage.

Tighten fasteners with torque wrench. Add recommended amount of correct viscosity, fresh, clean refrigerant oil.

Compressor can be bench tested for external seal leakage prior to installation. Look at Fig. 34-50.

After compressor is installed, evacuate and charge the system. Operate the air conditioning controls to cycle the compressor on and off a number of times (engine running). This will burnish the clutch plates and provide better initial torque transfer.

Always use a manufacturer's manual when overhauling a compressor. Cleanliness should be emphasized. Air conditioning systems will not tolerate foreign materials. A liquid line filter should be installed to remove contamination from the system, Fig. 34-51. The filter will eliminate the need to flush the system following compressor repairs.

SYSTEM DIAGNOSIS CHART

Many makers provide very helpful diagnostic charts covering all aspects of their systems. One such chart is shown in Fig. 34-52. When available, use these charts

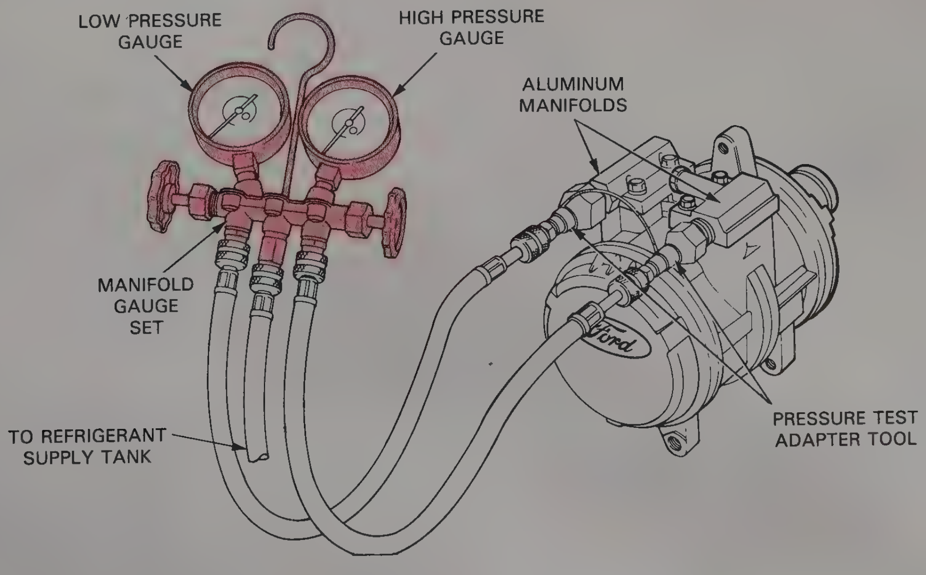


Fig. 34-50. Using a manifold gauge set to test a compressor for external leaks. (Ford)

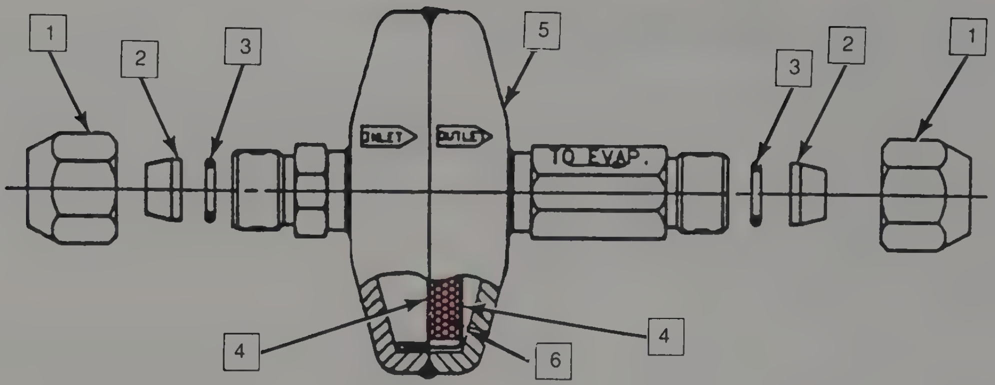


Fig. 34-51. The liquid line filter eliminates the need to flush the line following repairs. Follow the manufacturer's installation instructions. 1—Nut. 2—Ferrule. 3—O-ring. 4—Screen. 5—Filter housing. 6—Filtering pad. (GM)

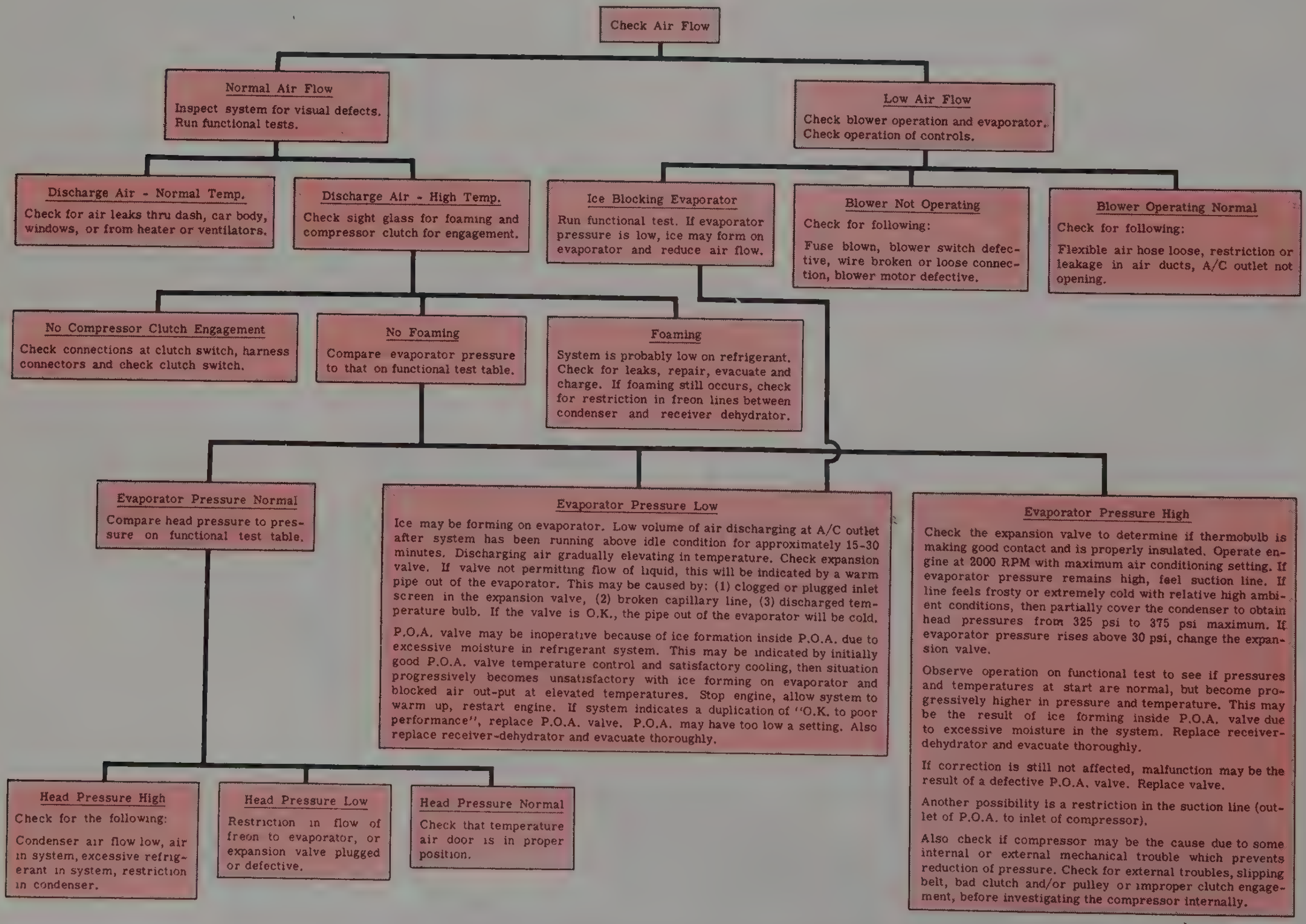
as they are helpful in pinpointing specific problems quickly and accurately.

AIR CONDITIONING SYSTEM SWITCHES

There are many special switches incorporated into air conditioning systems. When servicing these switches, always follow the manufacturer's recommendations. One type of switch is illustrated in Fig. 34-53.

WIRING AND VACUUM SYSTEMS

Modern auto air conditioning systems, especially in the fully automatic versions employing thermistors (temperature sensitive resistors sometimes referred to as "sensors"), have relatively complex wiring and



Check Air Flow

Normal Air Flow

Inspect system for visual defects. Run functional tests.

Low Air Flow

Check blower operation and evaporator. Check operation of controls.

Discharge Air - Normal Temp.

Check for air leaks thru dash, car body, windows, or from heater or ventilators.

Discharge Air - High Temp.

Check sight glass for foaming and compressor clutch for engagement.

Ice Blocking Evaporator

Run functional test. If evaporator pressure is low, ice may form on evaporator and reduce air flow.

Blower Not Operating

Check for following:

Fuse blown, blower switch defective, wire broken or loose connection, blower motor defective.

Blower Operating Normal

Check for following:

Flexible air hose loose, restriction or leakage in air ducts, A/C outlet not opening.

No Compressor Clutch Engagement

Check connections at clutch switch, harness connectors and check clutch switch.

No Foaming

Compare evaporator pressure to that on functional test table.

Foaming

System is probably low on refrigerant. Check for leaks, repair, evacuate and charge. If foaming still occurs, check for restriction in freon lines between condenser and receiver dehydrator.

Evaporator Pressure Normal

Compare head pressure to pressure on functional test table.

Evaporator Pressure Low

Ice may be forming on evaporator. Low volume of air discharging at A/C outlet after system has been running above idle condition for approximately 15-30 minutes. Discharging air gradually elevating in temperature. Check expansion valve. If valve not permitting flow of liquid, this will be indicated by a warm pipe out of the evaporator. This may be caused by: (1) clogged or plugged inlet screen in the expansion valve, (2) broken capillary line, (3) discharged temperature bulb. If the valve is O.K., the pipe out of the evaporator will be cold.

P.O.A. valve may be inoperative because of ice formation inside P.O.A. due to excessive moisture in refrigerant system. This may be indicated by initially good P.O.A. valve temperature control and satisfactory cooling, then situation progressively becomes unsatisfactory with ice forming on evaporator and blocked air out-put at elevated temperatures. Stop engine, allow system to warm up, restart engine. If system indicates a duplication of "O.K. to poor performance", replace P.O.A. valve. P.O.A. may have too low a setting. Also replace receiver-dehydrator and evacuate thoroughly.

Evaporator Pressure High

Check the expansion valve to determine if thermobulb is making good contact and is properly insulated. Operate engine at 2000 RPM with maximum air conditioning setting. If evaporator pressure remains high, feel suction line. If line feels frosty or extremely cold with relative high ambient conditions, then partially cover the condenser to obtain head pressures from 325 psi to 375 psi maximum. If evaporator pressure rises above 30 psi, change the expansion valve.

Observe operation on functional test to see if pressures and temperatures at start are normal, but become progressively higher in pressure and temperature. This may be the result of ice forming inside P.O.A. valve due to excessive moisture in the system. Replace receiver-dehydrator and evacuate thoroughly.

If correction is still not affected, malfunction may be the result of a defective P.O.A. valve. Replace valve.

Another possibility is a restriction in the suction line (outlet of P.O.A. to inlet of compressor).

Also check if compressor may be the cause due to some internal or external mechanical trouble which prevents reduction of pressure. Check for external troubles, slipping belt, bad clutch and/or pulley or improper clutch engagement, before investigating the compressor internally.

Head Pressure High

Check for the following:

Condenser air flow low, air in system, excessive refrigerant in system, restriction in condenser.

Head Pressure Low

Restriction in flow of freon to evaporator, or expansion valve plugged or defective.

Head Pressure Normal

Check that temperature air door is in proper position.

Fig. 34-52. Air conditioning refrigeration system problem diagnosis chart. (Buick)

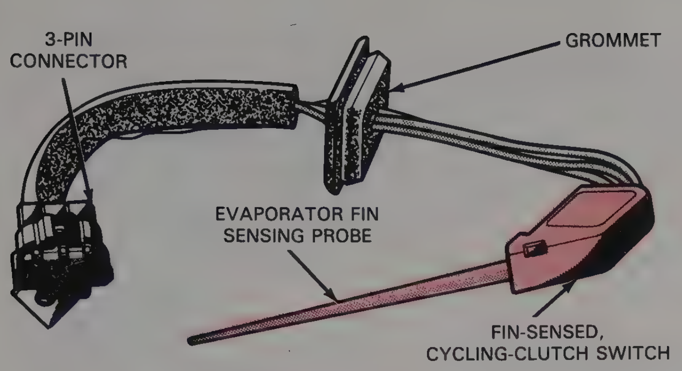

3-PIN CONNECTOR
GROMMET
EVAPORATOR FIN SENSING PROBE
FIN-SENSED, CYCLING-CLUTCH SWITCH

Fig. 34-53. One type of fin-sensed, cycling-clutch switch located in evaporator housing. This switch prevents evaporator freeze-up by signaling the electronic control module to cycle the compressor on until freeze-up is gone. This unit cannot be adjusted or repaired. (Chrysler)

vacuum control systems.

Refer to manufacturers' shop manuals for information regarding specific systems.

Figs. 34-54 and 34-55 illustrate a system analysis wiring diagram and a system analysis vacuum diagram. Typical system tools are shown in Fig. 34-56.

AUTOMOTIVE HEATING SYSTEMS — SERVICE AND REPAIR

The typical heater system provides three modes — heat, defrost, and vent. It is often integrated into the overall air conditioning system, Fig. 34-1.

An exploded view of a heater is shown in Fig. 34-57. Note the basic parts consisting of an electric motor, blower (fan), heater core, housing, and defroster hose along with vacuum and mechanical controls.

CHECKING HEATING SYSTEM

When possible, question the owner as to apparent problem, any unusual sounds, or other symptoms. Inspect system for coolant leakage. Check hoses for softening, cracking, kinks, or hardening. Inspect air intake for clogging, bent or loose ducting. Warm engine and operate heater controls while checking for proper response. Check heat control valve operation, blower speeds, defroster and vent operation. As required, check blower fuse, operation of vacuum motors, and mechanical controls.

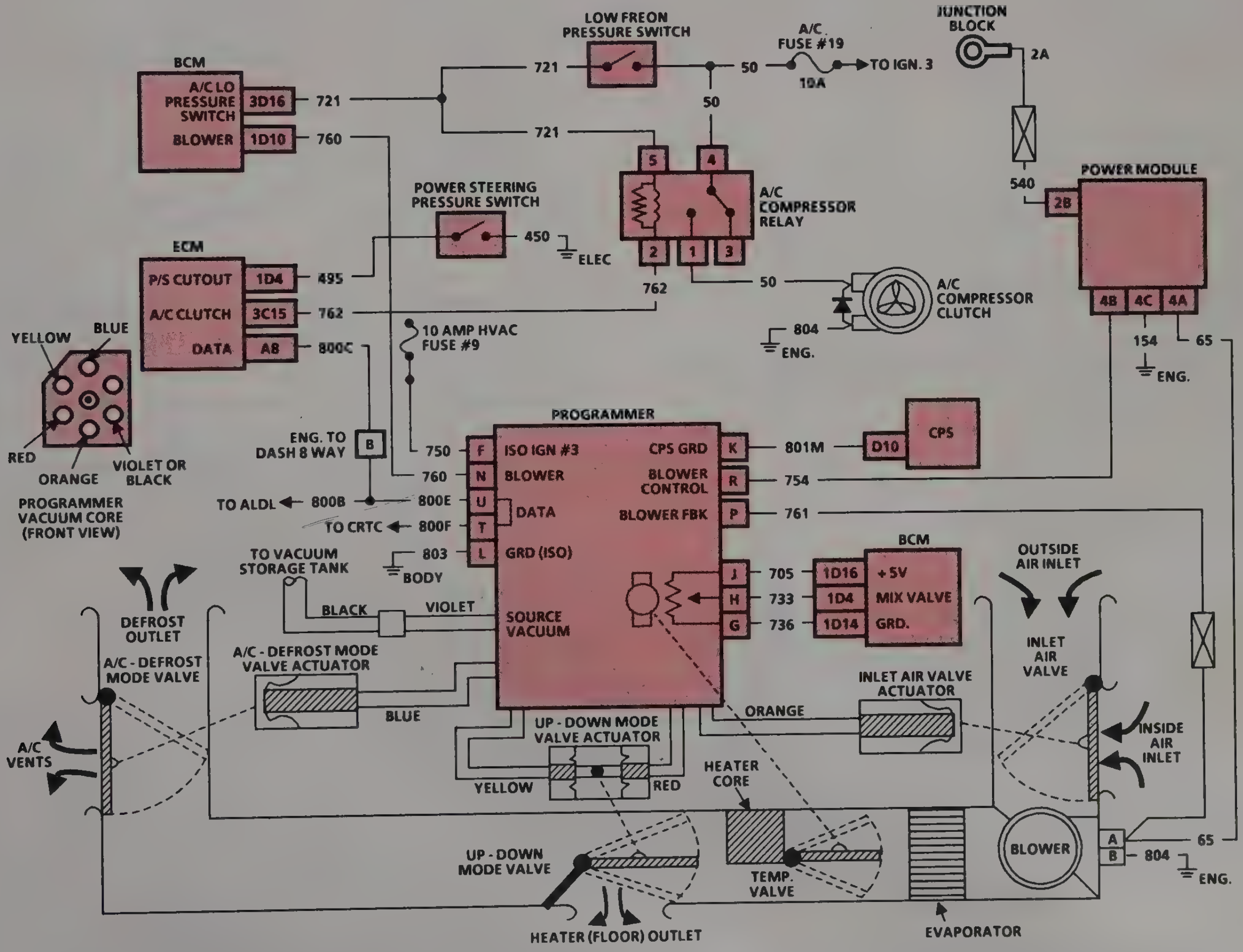
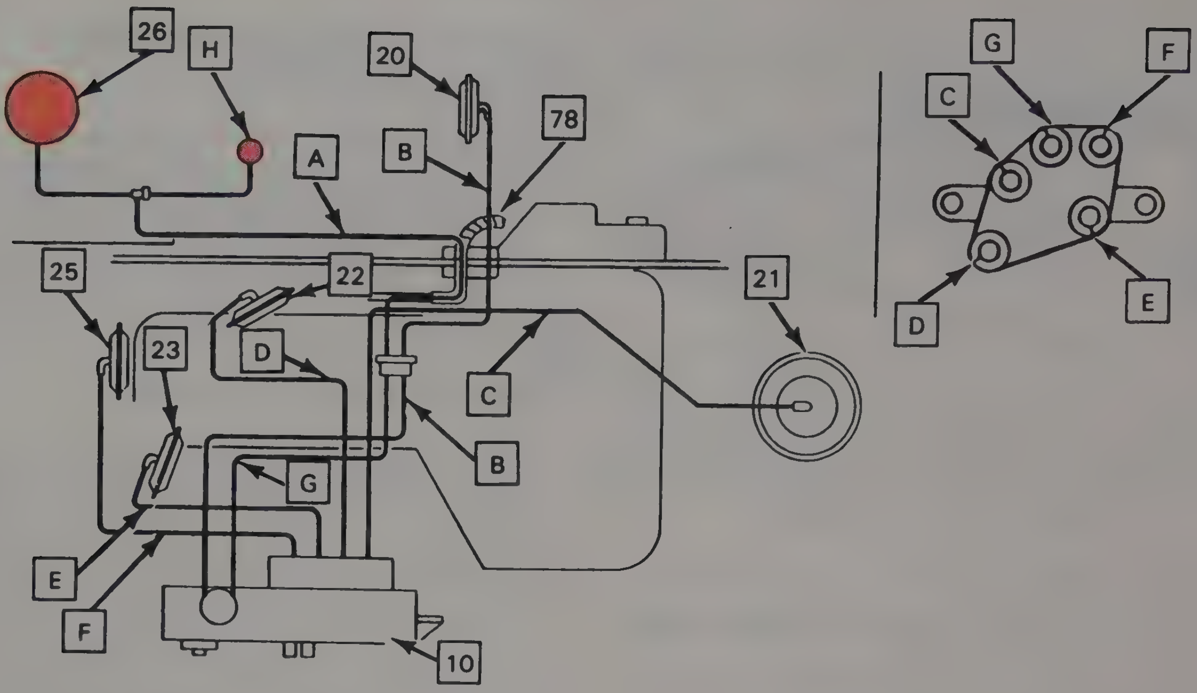

LOW FREON PRESSURE SWITCH
A/C FUSE #19
10A
TO IGN. 3
JUNCTION BLOCK
2A
BCM
A/C LO PRESSURE SWITCH
3D16
721
BLOWER
1D10
760
721
50
50
721
5
4
A/C COMPRESSOR RELAY
2
1
3
540
POWER MODULE
2B
POWER STEERING PRESSURE SWITCH
450
ELEC
ECM
P/S CUTOUT
1D4
495
A/C CLUTCH
3C15
762
DATA
A8
800C
762
50
A/C COMPRESSOR CLUTCH
804
ENG.
4B
4C
4A
154
65
ENG.
10 AMP HVAC FUSE #9
YELLOW
BLUE
RED
ORANGE
VIOLET OR BLACK
PROGRAMMER VACUUM CORE (FRONT VIEW)
ENG. TO DASH 8 WAY
B
PROGRAMMER
750
F
ISO IGN #3
760
N
BLOWER
TO ALDL
800B
800E
U
DATA
TO CRTC
800F
T
803
L
GRD (ISO)
BODY
CPS GRD
K
801M
D10
CPS
BLOWER CONTROL
R
754
BLOWER FBK
P
761
TO VACUUM STORAGE TANK
BLACK
VIOLET
SOURCE VACUUM
BCM
J
705
1D16
+5V
H
733
1D4
MIX VALVE
G
736
1D14
GRD.
OUTSIDE AIR INLET
INLET AIR VALVE
DEFROST OUTLET
A/C - DEFROST MODE VALVE
A/C - DEFROST MODE VALVE ACTUATOR
BLUE
A/C VENTS
UP - DOWN MODE VALVE ACTUATOR
ORANGE
INLET AIR VALVE ACTUATOR
INSIDE AIR INLET
YELLOW
RED
HEATER CORE
UP - DOWN MODE VALVE
TEMP. VALVE
BLOWER
A
B
65
804
ENG.
HEATER (FLOOR) OUTLET
EVAPORATOR

Fig. 34-54. A good air conditioning system wiring diagram is very helpful in diagnostic work. (Buick)



A	BLACK HOSE				
B	GRAY HOSE	G	VIOLET HOSE	22	UPPER MODE ACTUATOR
C	ORANGE HOSE	H	TO VACUUM SOURCE	23	LOWER MODE ACTUATOR
D	RED HOSE	10	CONTROL ASSEMBLY	25	DEFROSTER ACTUATOR
E	TAN HOSE	20	HOT WATER VALVE ACTUATOR	26	VACUUM TANK
F	BLUE HOSE	21	AIR INLET ACTUATOR	78	AIR CONDITIONING HARNESS

Fig. 34-55. Air conditioning vacuum control system diagram. (Pontiac)

TESTING HEATER CORE

If the heater core is suspected of leaking, conduct a cooling system pressure test. Make certain that any leak is not originating at the hose-to-core attachment point.

BLOWER MOTOR TESTING

As needed, test blower motor both for VOLTAGE DRAW and AMPERAGE (current) DRAW. Make recommended hookup for specific vehicle at hand and test as specified by manufacturer.

HEATING SYSTEM DIAGNOSIS

For further diagnostic information, see the section on PROBLEM DIAGNOSIS at the end of this chapter.

SUMMARY

Air conditioning systems may be of the manually controlled, or fully automatic type. The automatic system cleans, dehumidifies, and adjusts the temperature of the incoming air. The air is first cooled and then, if needed, heated to the desired level.

Refrigerant-12 is the cooling medium used in automotive refrigeration systems.

The receiver-dehydrator acts as a storage tank for high-pressure liquid refrigerant when located between the condenser and evaporator (high side). When used on the low side (between evaporator and compressor), it is often called an accumulator. In this case, it can contain R-12 vapor as well as some liquid. It also cleans and removes moisture.

From the receiver (when on high side), the liquid refrigerant travels to the expansion valve or orifice tube. The expansion valve meters a specific amount of refrigerant liquid into the evaporator. The refrigerant enters the evaporator as a low-pressure liquid.

Once in the evaporator, the low-pressure liquid draws heat from the finned evaporator coils and begins to boil or vaporize. As the liquid passes through the evaporator, it turns into a low-pressure vapor. This vaporizing action makes the evaporator finned coils extremely cold and thus cools the air passing over them.

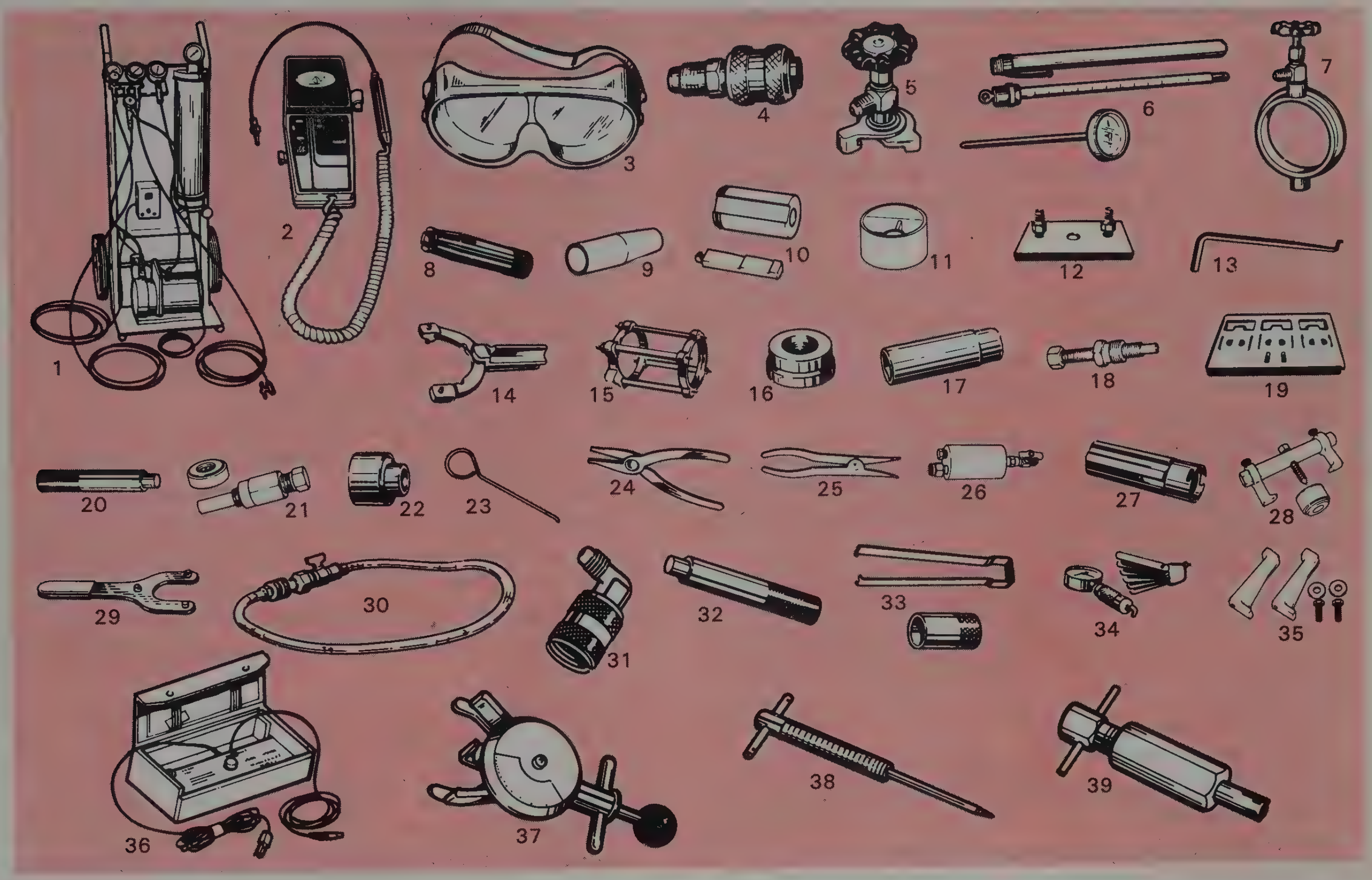

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Fig. 34-56. Typical air conditioning system service tools. 1—Portable charging station. 2—Battery powered leak detector. 3—Goggles. 4—Straight adapter. 5—R-12 dispensing valve. 6—Pocket thermometer. 7—Domed R-12 dispensing valve. 8—Compressor shaft seal installer and remover. 9—Oil seal protector. 10—O-ring installer. 11—Compressor support block. 12—Compressor test set. 13—O-ring remover. 14—Compressor holding fixture. 15—Compressing fixture. 16—Pulley bearing remover. 17—9/16 in. nut socket (thin walled). 18—Hub and clutch drive plate assembly remover. 19—Piston tray. 20—Needle bearing installer. 21—Hub and drive plate installer. 22—Pulley bearing and pulley installer. 23—Oil pick-up tube remover. 24—Snap ring pliers. 25—Snap ring pliers. 26—Oil injector. 27—Shaft seal remover and installer. 28—Compressor pulley puller kit. 29—Clutch hub holding tool. 30—Oil injector line. 31—90° elbow adapter. 32—Driver handle. 33—Seal seat remover and installer. 34—Feeler gauge set. 35—Pulley hub puller set. 36—A/C powered leak detector. 37—Belt tension gauge. 38—Orifice tube extractor. 39—Orifice tube remover. (Chevrolet)

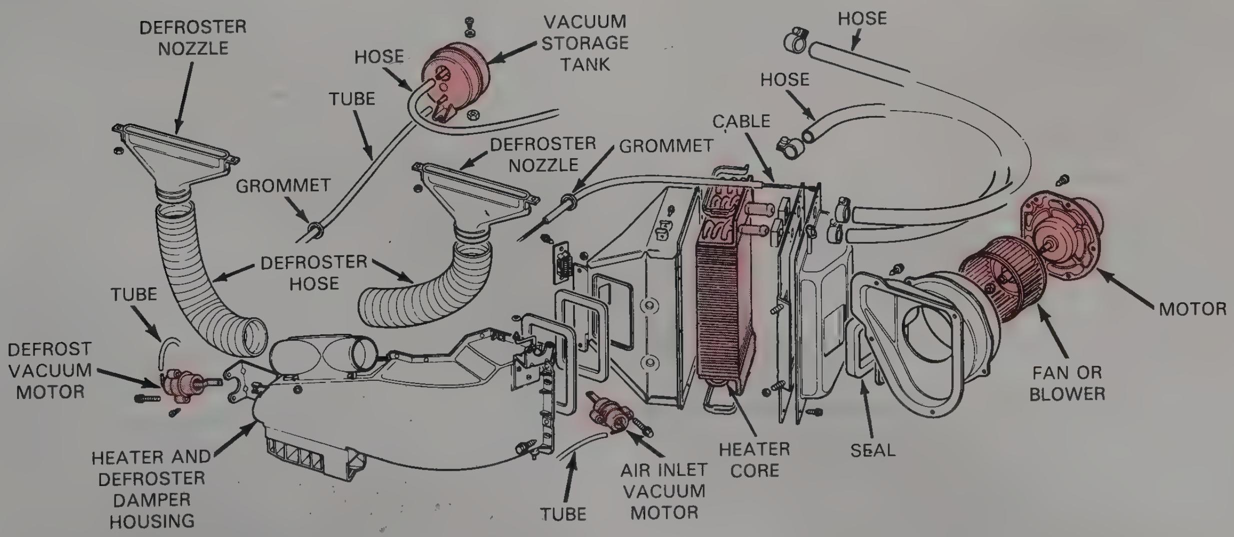

DEFROSTER NOZZLE
HOSE
VACUUM STORAGE TANK
HOSE
HOSE
TUBE
CABLE
DEFROSTER NOZZLE
GROMMET
GROMMET
DEFROSTER HOSE
TUBE
MOTOR
DEFROST VACUUM MOTOR
FAN OR BLOWER
HEATER AND DEFROSTER DAMPER HOUSING
HEATER CORE
SEAL
AIR INLET VACUUM MOTOR
TUBE

Fig. 34-57. Exploded view of typical heater system. Study part names and relationships. (Jeep)

The evaporator also dehumidifies and cleans the incoming air.

From the evaporator, the low-pressure vapor travels either directly to the compressor, or as is true in many systems, through a suction throttling valve. The suction throttling valve controls the pressure within the evaporator and prevents freezing of the evaporator coils.

On many systems, either a pressure or temperature switch is used to cycle the compressor on and off to control freezing. From the suction throttling valve or the evaporator, the vapor travels to the suction side of the compressor. On some systems, it travels through the accumulator first.

The compressor draws in a charge of low-pressure vapor and compresses it into a charge of high-pressure vapor. The compressor forces the high-pressure vapor into the condenser.

The condenser, placed in front of the radiator and cooled by the airflow created by the fan and the forward motion of the car, cools the hot, high-pressure vapor. As the vapor passes through the condenser, its temperature is lowered to the point that it turns back into a high-pressure liquid.

The high-pressure liquid travels from the condenser to the receiver-dehydrator where it begins another cycle through the system. The various parts of the system are connected by tubing and/or hose.

The system is protected from excessive pressure by a safety valve. One or more mufflers may be used to quiet system noises. A sight glass may be used to view the stream of liquid refrigerant.

Always follow safety rules dealing with refrigeration service:

1. Always wear goggles and gloves when servicing the system.
2. Keep service area well ventilated.
3. Do not discharge refrigerant directly into the service area.
4. Do not subject a system to high temperatures.
5. Keep refrigerant away from your skin.
6. Never leave a refrigerant tank uncapped.
7. Never overheat the refrigerant tank.
8. Never fill a tank completely.
9. Never breathe smoke produced when refrigerant contacts a flame.
10. For leak detection, use an electronic tool.
11. Never connect the R-12 one pound cans to the system high side.
12. Never transport R-12 containers in passenger compartment.

Observe recommended service precautions to prevent contamination of the system. Remember the enemies of refrigeration systems are DIRT, WATER, and AIR.

Discharge the system before opening any connection.

Protect hose and tubing from vibration, kinks, sharp bends, and heat. Torque all connections.

The removal of any part of the system (with exception of compressor when it can be isolated) requires the following steps:

1. Test for leaks.
2. Discharge system.
3. Replace part.
4. Evacuate system.
5. Charge system.
6. Test again for leaks.

The manifold gauge set is connected into the system by means of Schrader valves or by regular gauge connections. Gauge valves must be in the front-seated position before connecting set.

For leak detection, use an electronic tool. Detector probe should be used slowly and close to test area. Set up and use as directed by manufacturer.

Unless specified otherwise, discharge a system slowly to prevent compressor oil from being drawn out. Discharge refrigerant into a container placed in a service exhaust outlet. Check container for any oil lost. The same amount of new, fresh oil must be placed back in the system.

System must be evacuated for the recommended length of time at 26-28 in. of vacuum. Deduct 1 in. of vacuum for each 1,000 ft. (304 M) of elevation. Evacuation removes air and moisture from the system.

Charge the system with a partial charge following evacuation. Test for leaks. Discharge and make final evacuation.

Charge the system with the specified amount of refrigerant. Charging may be done using a tank or 1 lb. (0.45 kg) cans. If the refrigerant tank is heated for charging, use water no hotter than 125°F (52°C).

The high-pressure side of the system should be charged with liquid R-12. Charge the low side with vapor only, unless specified otherwise (such as with C.C.O.T. system).

When the charge is drawn from the top of the tank, it will be in vapor state. When drawn from the bottom of the tank (or if tank is upside-down) the charge will be in the liquid state.

The amount of compressor oil in the system is critical. It may be checked, in some instances, by measuring the level in the compressor. In other setups, the compressor must be removed and the oil drained and measured.

When an evaporator, condenser, receiver, or other part is replaced, a specific amount of oil must be added to the new unit to replace that remaining in the old. Oil level need not be checked in a system in which NO leaks are present. Some systems permit oil to be injected into the system without discharging.

Flush the refrigeration system with refrigerant or with dry nitrogen if contaminated.

A number of simple checks will quite often disclose the trouble in a malfunctioning system:

1. Make certain the system is operated correctly.

2. Check drive belt condition and tension.
3. Check compressor magnetic clutch operation.
4. Check sight glass.
5. Check system lines and connections.
6. Check system airflow.
7. Check radiator and condenser or bug screen for bugs, dirt, and debris.

Performance testing involves comparing system pressure and discharge air temperature with specified pressures and temperatures related to ambient air temperature and humidity.

Inspect the system as soon as possible following collision damage.

Remember that R-12 will severely tarnish brightwork (bumpers, stripping, etc.), especially in the presence of water.

PROBLEM DIAGNOSIS: AIR CONDITIONING SYSTEM

PROBLEM: EXCESSIVE PRESSURE (HIGH SIDE OF SYSTEM)

Possible Cause	Correction
1. Air in system.	1. Leak test. Correct leak. Discharge. Evacuate and charge system.
2. Overcharge of refrigerant.	2. Discharge. Evacuate and charge with correct amount.
3. Engine overheating.	3. Correct cause of overheating.
4. Fan belt slipping.	4. Adjust or replace belt.
5. Clogged condenser core.	5. Remove bugs, leaves, dirt, and other debris.
6. Excessive oil in system.	6. Remove excess oil.
7. Restriction in lines, condenser, or receiver-dehydrator.	7. Remove part and clean or replace as needed.
8. Expansion valve superheat setting too low.	8. Replace unit.
9. Filters or screens plugged.	9. Remove. Clean or replace as needed.

PROBLEM: INSUFFICIENT PRESSURE (HIGH SIDE OF SYSTEM)

Possible Cause	Correction
1. Insufficient charge.	1. Charge system with recommended amount.
2. Defective compressor valves.	2. Replace valves.
3. Expansion valve or suction throttling valve stuck open permitting excessive flow of refrigerant to compressor.	3. Replace valve.

PROBLEM: EXCESSIVE PRESSURE (LOW SIDE OF SYSTEM)

Possible Cause	Correction
1. Defective expansion valve.	1. Replace valve.
2. Insufficient oil in system.	2. Add oil.
3. Expansion valve thermal bulb not in good contact with evaporator outlet pipe.	3. Clean connection and tighten. Insulate as required.
4. Defective suction throttling valve.	4. Replace valve.
5. Expansion valve frozen.	5. Replace receiver-dehydrator. Recharge system.
6. Compressor clutch slipping.	6. Repair or replace clutch.
7. Restricted suction line.	7. Clean or replace.
8. Slipping compressor drive belt.	8. Adjust or replace.
9. Defective compressor valves.	9. Replace valves.
10. Moisture in system.	10. Repair leaks. Replace receiver-dehydrator. Evacuate and charge system.

PROBLEM: INSUFFICIENT PRESSURE (LOW SIDE OF SYSTEM)

Possible Cause	Correction
1. Insufficient charge.	1. Charge with recommended amount of refrigerant.
2. Insufficient airflow.	2. Clean evaporator core. Check blower operation.
3. Defective suction throttling valve.	3. Repair. Adjust or replace as needed.
4. Defective expansion valve.	4. Replace valve.
5. Liquid line clogged.	5. Replace line.
6. Restricted suction line, receiver-dehydrator, or expansion valve.	6. Replace line, receiver-dehydrator, or expansion valve.
7. Temperature control thermostat does not cut out.	7. Replace thermostat.
8. Compressor clutch will not disengage.	8. Repair or replace clutch.

PROBLEM: WATER DISCHARGED WITH AIRFLOW

Possible Cause	Correction
1. Clogged evaporator drain.	1. Open drain.

PROBLEM: SYSTEM NOISY

Possible Cause	Correction
1. Compressor mounting loose.	1. Tighten mounting fasteners.
2. Compressor belt slipping.	2. Adjust belt tension.
3. Refrigeration system lines vibrating.	3. Install clamps and insulators.
4. Blower motor defective.	4. Replace motor.
5. Loose air ducts.	5. Tighten ducts.
6. Excessive oil in system.	6. Drain and install correct amount of oil.
7. Blower blades striking housing.	7. Adjust for clearance.
8. Obstructions in airflow system.	8. Remove obstructions.
9. Defective compressor.	9. Repair or replace as required.
10. Defective expansion valve.	10. Replace expansion valve.

PROBLEM: AIRFLOW CONTAINS OBJECTIONABLE ODOR

Possible Cause	Correction
1. Odor producing material on evaporator core.	1. Clean evaporator core.
2. Outside odors drawn in by airflow system.	2. Instruct driver as to reason.

PROBLEM: INSUFFICIENT AIRFLOW

Possible Cause	Correction
1. Defective blower.	1. Replace blower.
2. Clogged ducts.	2. Clean ducts.
3. Evaporator core icing.	3. Replace suction throttling valve or thermostatic switch.
4. Loose duct hose connections.	4. Attach flexible hose securely.
5. Shut-off valves in air discharge outlets closed.	5. Instruct owner as to proper operation.
6. Dirty evaporator core.	6. Clean core.
7. Airflow system control doors malfunctioning.	7. Check vacuum system.
8. Blower disconnected or circuit fuse blown.	8. Connect or replace fuse.

PROBLEM: EVAPORATOR VALVE

Possible Cause	Correction
1. Defective or improperly adjusted suction throttling valve.	1. Adjust or replace valve.
2. Defective thermostatic switch.	2. Replace switch.
3. Compressor clutch will not disengage.	3. Repair clutch.
4. Thermostat capillary tube not in proper contact with evaporator core.	4. Place tube in proper contact with core.

PROBLEM: EVAPORATOR WILL NOT COOL AIRFLOW

Possible Cause	Correction
1. Defective thermostatic switch.	1. Replace switch.
2. Defective suction throttling valve.	2. Replace STV.
3. Improperly adjusted STV.	3. Adjust STV.
4. Broken or slipping compressor belt.	4. Replace or adjust tension.
5. Compressor defective.	5. Replace compressor.
6. Compressor clutch inoperative.	6. Repair clutch.
7. Defective expansion valve.	7. Replace expansion valve.
8. Insufficient refrigerant charge.	8. Charge system.
9. Excessive oil in system.	9. Drain. Add correct amount.
10. Expansion valve screen clogged.	10. Clean screen or replace valve.
11. Bugs, leaves, other debris on condenser.	11. Clean condenser.
12. Fan belt slipping or broken.	12. Adjust tension or replace belt.
13. Excessive refrigerant charge.	13. Charge correctly.
14. Moisture in system.	14. Repair leaks. Install new receiver-dehydrator and charge.
15. Air in system.	15. Repair leaks. Charge.
16. Evaporator core dirty.	16. Clean core.
17. Clogged or kinked lines.	17. Clean or replace lines.
18. Clogged receiver-dehydrator.	18. Install new receiver-dehydrator.
19. Engine overheating.	19. Correct cause.
20. Clogged evaporator drain.	20. Clean drain.
21. Evaporator icing.	21. (See Evaporator Icing.)
22. Clogged orifice tube.	22. Replace orifice tube.

PROBLEM DIAGNOSIS: HEATER SYSTEM

PROBLEM: BLOWER DOES NOT OPERATE CORRECTLY

Possible Cause	Correction
1. Blown fuse.	1. Replace fuse. Fix short if needed.
2. Defective motor.	2. Replace motor.
3. Faulty blower resistor.	3. Replace resistor.
4. Defective switch.	4. Replace switch.
5. Loose connections.	5. Clean and tighten.
6. Faulty wiring.	6. Replace wiring.

PROBLEM: INADEQUATE HEATING

Possible Cause	Correction
1. Faulty blower.	1. Replace blower.
2. Heat valve control inoperative.	2. Free control and make certain valve control functions.
3. Defective heat control valve.	3. Replace valve.
4. Clogged air inlet.	4. Clean.
5. Bent, kinked inlet ducting.	5. Straighten or replace.
6. Dirty heater core.	6. Clean core.
7. Control doors inoperative.	7. Free and make certain they operate properly.
8. Faulty controls.	8. Adjust or replace as needed.
9. Faulty heater operation.	9. Advise owner as to proper operation.
10. Faulty engine thermostat.	10. Replace thermostat.
11. Plugged or kinked heater hoses.	11. Straighten or replace.
12. Low engine coolant level.	12. Fill. Check for leaks.
13. Clogged heater core.	13. Reverse flush.

PROBLEM: INADEQUATE DEFROST

Possible Cause	Correction
1. Defective blower switch.	1. Replace switch.
2. Defective or inoperative blower motor.	2. Repair or replace.
3. Defroster ducts are disconnected.	3. Connect ducts.
4. Improver control door operation.	4. Free, adjust, and check.
5. Clogged defroster outlets.	5. Clean outlets.

PROBLEM: DEFROST CAUSES WINDSHIELD FOGGING

Possible Cause	Correction
1. Leaking heater core.	1. Repair or replace core.
2. Loose hose to core fitting.	2. Tighten fitting.
3. Water (rain, washing, etc.) entering system.	3. Check seals for leaks.

PROBLEM: EXCESSIVE HEAT

Possible Cause	Correction
1. Faulty operation of controls.	1. Advise driver in correct use.
2. Controls loose or stuck.	2. Connect and check for proper operation.

KNOW THESE TERMS

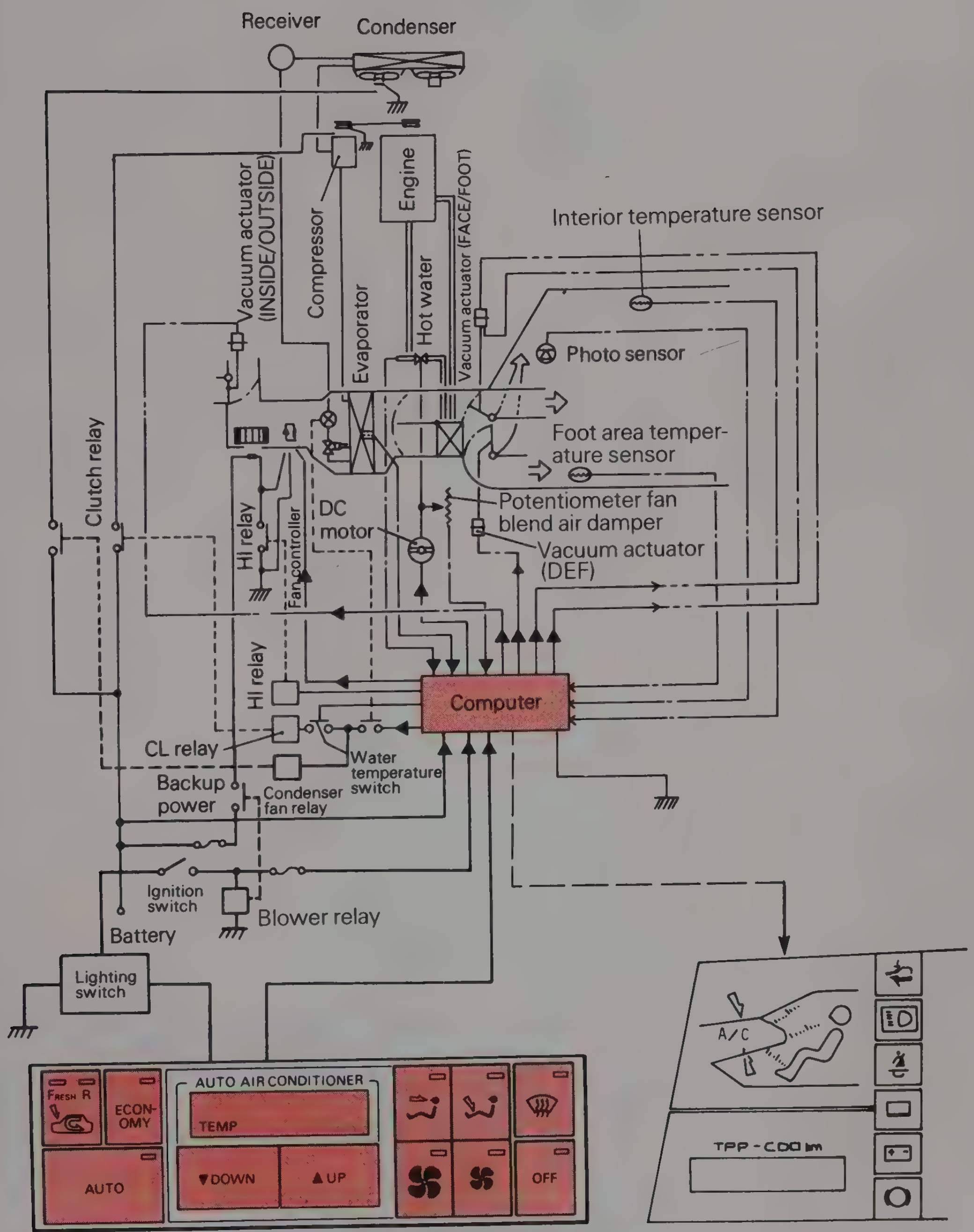
Refrigerant-12 (R-12), Evaporator, Accumulator, Condenser, Receiver-dehydrator, Expansion valve, Equalizer line, Capillary tube, Sight glass, Suction throttling valve, Pilot operated absolute (POA), Radial compressor, Axial compressor, Refrigeration cycle, "Crack" a fitting, Service valve, Charging station, Manifold gauge set, Schrader valve, Halide torch, Electronic leak detector, Phosgene gas, Vacuum pump, Vapor charging, Liquid charging, Refrigerant oil, Magnetic clutch, Thermal bulb, Dehumidify, Orifice tube, High-side, Low-side, Ambient air temperature.

QUIZ - Chapter 34

1. The air conditioning system ________________, ________________, and dehumidifies the air entering the car.
2. Refrigerant-12 boils at minus ___________°F at sea level atmospheric pressure.
3. Refrigerant-12 will eventually wear out from endless cycles through the system and should thus be replaced at specified intervals. True or False?
4. As the pressure is increased on Refrigerant-12, the boiling point ________________.
5. The receiver-dehydrator is used to store ________

_________ in addition to cleaning and removing the moisture from it.

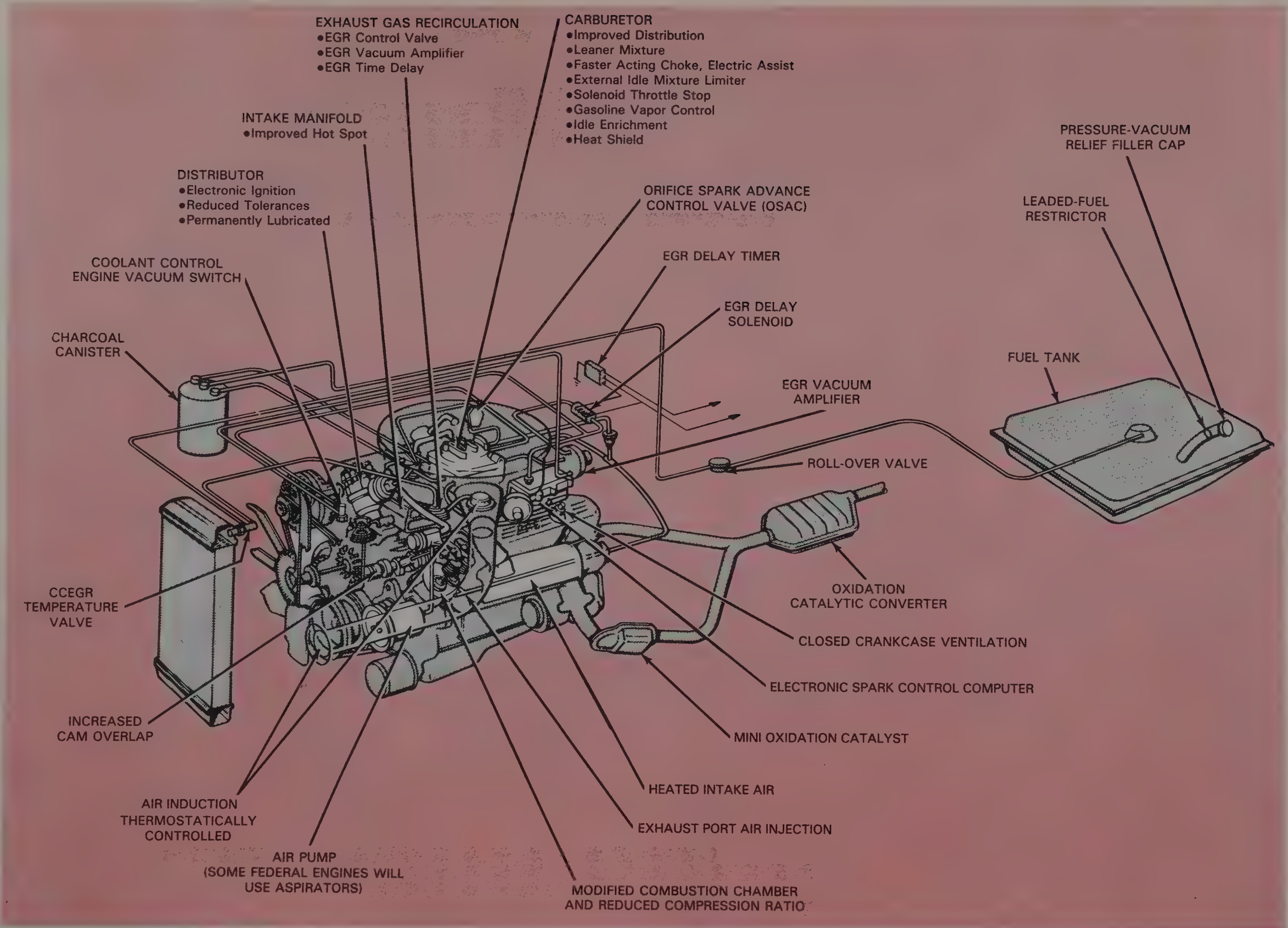
6. The _________ _________ receives _________ pressure, _________ refrigerant and admits _________ pressure, _________ refrigerant into the evaporator.
7. The evaporator changes refrigerant vapor back into liquid refrigerant. True or False?
8. The suction throttling valve controls:
   a. Engine rpm.
   b. Carburetor choke setting.
   c. Evaporator pressure.
   d. Receiver-dehydrator temperature.
9. The compressor draws in _________ state refrigerant and forces out _________ state refrigerant.
10. The condenser:
    a. Changes refrigerant vapor into liquid.
    b. Changes liquid refrigerant into vapor.
    c. Controls the evaporator temperature.
    d. Removes moisture from the air entering the car.
11. List two items that can be used to prevent icing of the evaporator core.
12. All compressors are double-acting. True or False?
13. Compressor noise can be reduced by placing a _________ in the system.
14. The sight glass permits:
    a. Viewing liquid refrigerant.
    b. Viewing refrigerant vapor.
    c. Checking refrigerant for icing.
    d. Checking oil level in compressor.
15. List ten safety rules regarding working with, on, or around refrigeration systems.
16. Describe the first aid procedure involved when refrigerant gets in the eyes.
17. Dirt, _________, and _________ are the worst enemies of the refrigeration system.
18. List eight general service precautions that must be observed to prevent system contamination.
19. When torquing a connection that uses aluminum for one end and steel for the other, use the torque values given for _________.
20. The manifold gauge set assists in:
    a. Checking system pressures.
    b. Evacuating the system.
    c. Discharging the system.
    d. All of above.
21. A special _________ is needed to connect the manifold gauge set to Schrader valves.
22. Before connecting the manifold gauge set into the system, the gauge valves must be in the _________ position.
23. When a part is to be replaced in the system, list (in the correct order) the six steps that should be taken regarding system evacuation, charging, etc.
24. Always evacuate the system before checking for leaks. True or False?
25. Never _________ the fumes generated when refrigerant contacts a flame.
26. Always discharge the system as fast as possible. True or False?
27. To evacuate the system properly, the system must be subjected to a vacuum of around:
    a. 8 in.
    b. 28 in.
    c. 48 in.
28. When heating a refrigerant tank, never use water exceeding _________ °F.
29. The system should be charged with a specific amount (by weight) of refrigerant. True or False?
30. Some systems require complete discharging in order to check compressor oil level. True or False?
31. A high quality engine oil is satisfactory for use in refrigeration systems. True or False?
32. List five quick diagnostic checks that will often uncover the trouble with a system.
33. Performance testing involves checking:
    a. Discharge air temperature.
    b. System pressures.
    c. Ambient air temperature and humidity.
    d. All of above.
34. When charging a system, unless specifically required for exact system, never add liquid R-12 to:
    a. System high side.
    b. System low side.
    c. Condenser.
    d. Evaporator.
35. An orifice tube has a:
    a. Variable venturi opening.
    b. No opening.
    c. A fixed opening.
    d. Multiple openings.
36. The suction accumulator is located between the evaporator and the _________.
37. The C.C.O.T. (Cycling Clutch Orifice Tube) system uses a POA valve to control evaporator pressure. True or False?
38. When discharging the system, it is good practice to discharge into a container so that:
    a. R-12 will not be lost.
    b. Amount of R-12 discharged can be measured.
    c. Area will not be contaminated.
    d. Any oil removed may be measured.
39. When checking for leaks, always use an _________ type leak detector.
40. Upright R-12 containers will discharge R-12 _________ while upside-down containers will discharge R-12 _________.
41. Never connect one-pound R-12 containers into:
    a. System high side.
    b. System low side.
    c. Thermocouple.
    d. POA valve.


Receiver
Condenser
Vacuum actuator (INSIDE/OUTSIDE)
Compressor
Engine
Evaporator
Hot water
Vacuum actuator (FACE/FOOT)
Interior temperature sensor
Photo sensor
Foot area temperature sensor
Potentiometer fan blend air damper
Vacuum actuator (DEF)
DC motor
Clutch relay
HI relay
Fan controller
HI relay
Computer
CL relay
Water temperature switch
Backup power
Condenser fan relay
Ignition switch
Blower relay
Battery
Lighting switch
FRESH R
ECONOMY
AUTO AIR CONDITIONER
TEMP
AUTO
▼DOWN
▲UP
OFF
A/C
TPP-CDD km

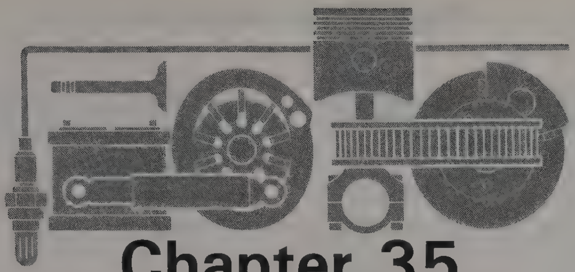
Control panel

Air-conditioning graphic display

A temperature feedback control air conditioning system. The heart of this system is the computer, which analyzes signals from various sensors prior to adjusting the temperature. (Chrysler)


EXHAUST GAS RECIRCULATION
•EGR Control Valve
•EGR Vacuum Amplifier
•EGR Time Delay
CARBURETOR
•Improved Distribution
•Leaner Mixture
•Faster Acting Choke, Electric Assist
•External Idle Mixture Limiter
•Solenoid Throttle Stop
•Gasoline Vapor Control
•Idle Enrichment
•Heat Shield
INTAKE MANIFOLD
•Improved Hot Spot
PRESSURE-VACUUM RELIEF FILLER CAP
DISTRIBUTOR
•Electronic Ignition
•Reduced Tolerances
•Permanently Lubricated
ORIFICE SPARK ADVANCE CONTROL VALVE (OSAC)
LEADED-FUEL RESTRICTOR
COOLANT CONTROL ENGINE VACUUM SWITCH
EGR DELAY TIMER
EGR DELAY SOLENOID
CHARCOAL CANISTER
FUEL TANK
EGR VACUUM AMPLIFIER
ROLL-OVER VALVE
OXIDATION CATALYTIC CONVERTER
CCEGR TEMPERATURE VALVE
CLOSED CRANKCASE VENTILATION
ELECTRONIC SPARK CONTROL COMPUTER
INCREASED CAM OVERLAP
MINI OXIDATION CATALYST
AIR INDUCTION THERMOSTATICALLY CONTROLLED
HEATED INTAKE AIR
EXHAUST PORT AIR INJECTION
AIR PUMP (SOME FEDERAL ENGINES WILL USE ASPIRATORS)
MODIFIED COMBUSTION CHAMBER AND REDUCED COMPRESSION RATIO

Schematic showing emission control devices and exhaust system used by one maker on one specific model. (Chrysler)



Chapter 35

EXHAUST AND EMISSION CONTROL SYSTEM SERVICE

After studying this chapter, you will be able to:

☐ Explain heat control valve operation, service, and repair.
☐ Describe exhaust manifold removal and installation.
☐ Summarize muffler design and operation.
☐ Remove and install a muffler.
☐ Describe exhaust and tail pipe removal and installation.
☐ Use special exhaust system service tools.
☐ Explain catalytic converter construction and operation.
☐ Remove, install, and service a catalytic converter.
☐ Describe air injection system operation, service, and repair.
☐ Explain exhaust gas recirculation system operation, service, and repair.
☐ Summarize other common emission controls, their operation, servicing, and repair.
☐ Diagnose exhaust system and emission control problems.

EXHAUST SYSTEM — EXHAUST MANIFOLD

As the burned gases leave the engine cylinders, they pass into the EXHAUST MANIFOLD. The manifold is usually made of cast iron or stainless steel and is attached to the head with a series of fasteners. A manifold is designed to route the exhaust gases with a minimum of sharp bends. Once affixed to the engine, periodic service (other than lubrication of exhaust manifold heat control valve) is usually not required.

To remove the manifold, disconnect the exhaust pipe flange and any braces or tubing that may be connected to the manifold. Remove manifold fasteners. The use of penetrating oil and heat is sometimes required to remove the exhaust pipe-to-manifold fasteners.

When installing a manifold, all mounting surfaces must be clean. Use a file to remove burrs and bits of hardened gasket. Install new gaskets where needed. Torque fasteners in proper sequence. On the relatively thick, composition (not steel) manifold-to-head gaskets, the fasteners should be retorqued after the engine has been operated. This will bring fastener pressure back up to compensate for that lost due to the gasket flattening out following heating.

Use fastener locks when required to prevent fasteners (especially end ones) from loosening. Connect exhaust pipe (use new gasket) and hook up parts originally attached to the manifold.

Fig. 35-1 illustrates a typical exhaust manifold. Note that in this particular case, the intake manifold is connected to the exhaust manifold by a metal tube. The tube provides exhaust gases for EGR (exhaust gas

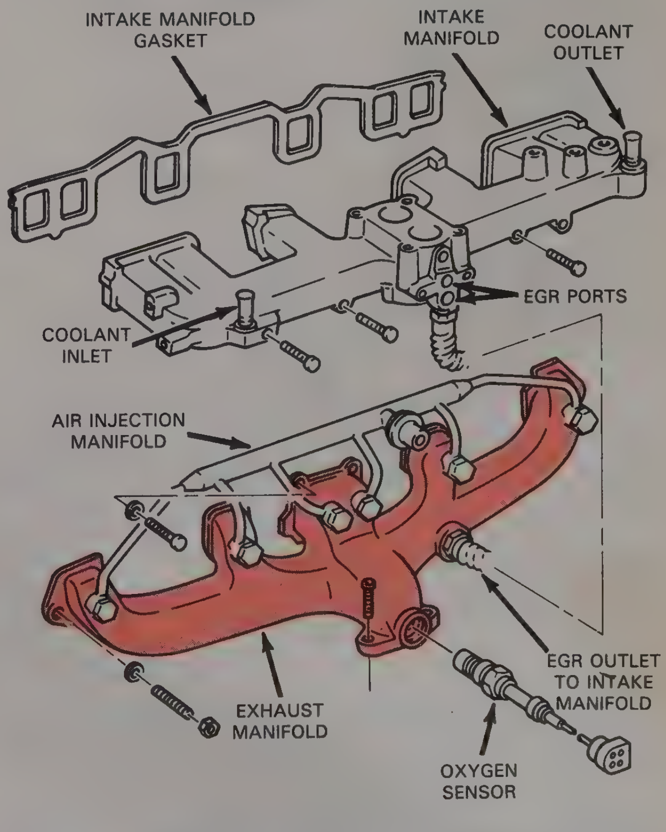


Fig. 35-1. Typical exhaust manifold as used on an in-line type engine. This one is for a six cylinder. (AMC)

recirculation) valve operation. Exhaust manifolds for V-type engines uses similar construction.

HEAT CONTROL VALVE

To provide heat to help vaporize the fuel charge during engine warm-up, a heat control valve may be installed in the exhaust manifold. It may also be between the exhaust manifold and exhaust pipe. The valve can be actuated by a bimetallic spring or by a vacuum motor (diaphragm unit).

Fig. 35-2 shows heat valve action with the engine hot, A, and cold, B. Note, in B, how the hot gases are directed to the floor of the intake manifold. There is a gradual change between the fully opened and closed positions of the valve.

The manifold heat control valve, shown in A and B of Fig. 35-2, is incorporated in the exhaust manifold. In C, the heat control valve is shown between the exhaust manifold and exhaust pipe. This is a popular arrangement on V-type engines.

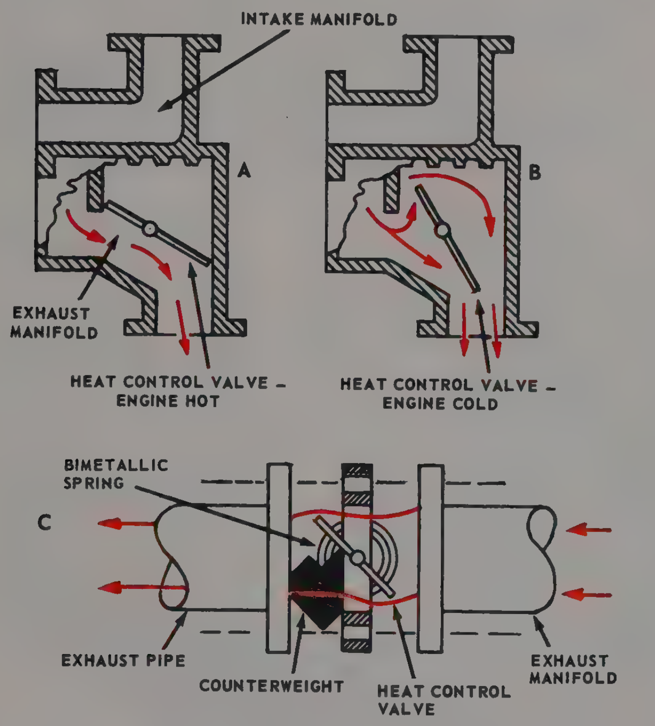

INTAKE MANIFOLD
A
B
EXHAUST MANIFOLD
HEAT CONTROL VALVE – ENGINE HOT
HEAT CONTROL VALVE – ENGINE COLD
BIMETALLIC SPRING
C
EXHAUST PIPE
COUNTERWEIGHT
HEAT CONTROL VALVE
EXHAUST MANIFOLD

Fig. 35-2. Two types of heat control valves. A—In-line engine type in HOT engine position. B—Valve has moved to COLD engine position. C—Typical V-type engine heat control valve.

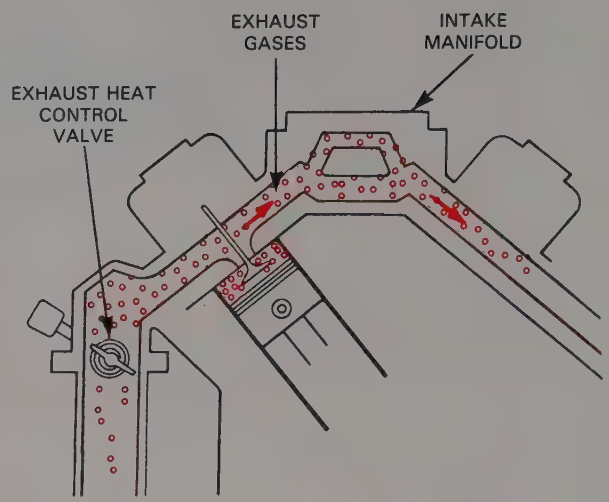

EXHAUST GASES
INTAKE MANIFOLD
EXHAUST HEAT CONTROL VALVE

Fig. 35-3. Exhaust heat control valve action directs exhaust gases to intake manifold to aid cold engine operation by warming fuel mixture. (Chevrolet)

On a typical V-type engine, only one exhaust manifold is fitted with a heat control valve. When it closes, the hot gases are forced to travel up through the heat riser and to the other exhaust manifold. They are then discharged, Fig. 35-3. As the gases pass through the intake manifold, the area beneath the carburetor is heated, thus aiding fuel vaporization during cold engine operation.

A vacuum motor operated heat valve is pictured in Fig. 35-4. With this setup, a thermal vacuum switch is used to apply enough engine vacuum to match engine temperature. When the engine is cold, full vacuum is applied. The valve is pulled closed. As engine warms, the vacuum signal weakens. When the engine reaches operating temperature, no vacuum is applied. The valve is kept open by spring pressure.

The heat control valve must be checked periodically to make certain the valve is free. For complete servicing instructions, refer to the chapter on fuel system service.

EXHAUST SYSTEM

The exhaust gas travels from the exhaust manifold into the EXHAUST PIPE. The exhaust pipe carries the gases to the catalytic converter(s), muffler(s), and

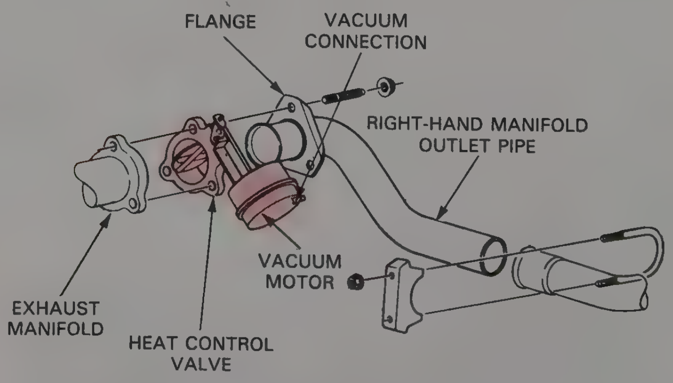

FLANGE
VACUUM CONNECTION
RIGHT-HAND MANIFOLD OUTLET PIPE
VACUUM MOTOR
EXHAUST MANIFOLD
HEAT CONTROL VALVE

Fig. 35-4. Vacuum motor operated exhaust heat control valve. Note absence of thermostatic spring. (Cadillac)

other parts. The catalytic converter lowers hydrocarbons (HC) and carbon monoxide (CO).

The muffler silences the exhaust sound and routes the gas into the tail pipe. The tail pipe carries the gas to either the end or the side of the vehicle where it is discharged into the atmosphere.

Some installations, in addition to a muffler, have a RESONATOR to further dampen the exhaust pulsations.

TWO TYPES OF EXHAUST SYSTEMS

Exhaust systems may be of the SINGLE type, Fig. 35-5, or the DUAL type, Fig. 35-6. Both may use resonators along with mufflers.

MUFFLER DESIGN

Mufflers should silence the exhaust effectively while providing freedom from objectionable "back pressure" (exhaust cannot pass through muffler fast enough and thus builds up pressure that cuts down engine efficiency).

Mufflers are generally one of three basic designs — REVERSE FLOW, STRAIGHT-THROUGH, and CHAMBERED PIPE.

One form of the baffled, reverse flow design is pictured in Fig. 35-7. This particular muffler is of double-wall construction and is coated for increased service life.

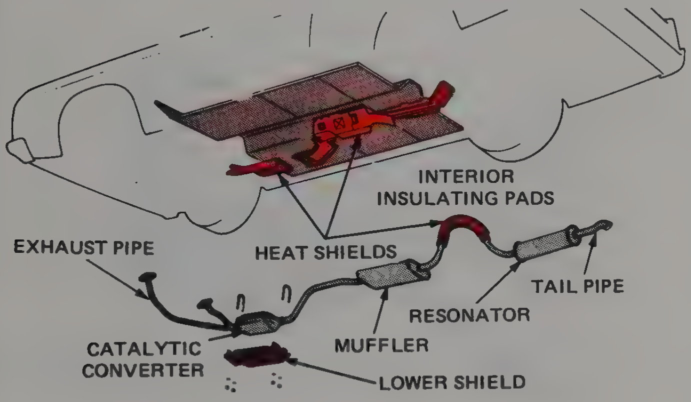

INTERIOR
INSULATING PADS
EXHAUST PIPE
HEAT SHIELDS
TAIL PIPE
RESONATOR
CATALYTIC
CONVERTER
MUFFLER
LOWER SHIELD

Fig. 35-5. Catalytic converter generates considerable heat. Make certain proper heat shielding is in place. This is a single exhaust system. (Plymouth)

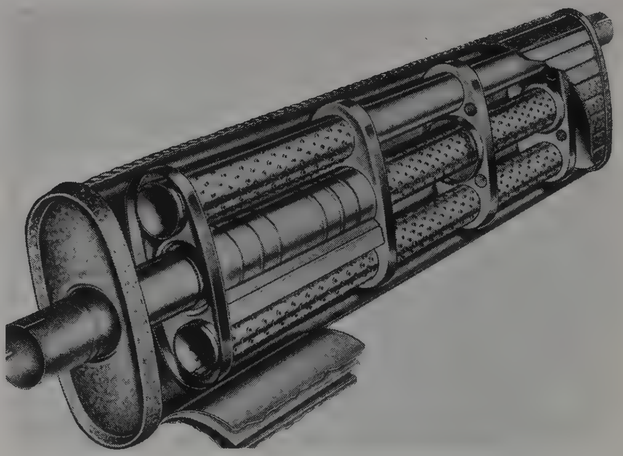


Fig. 35-7. One form of baffled, reverse flow muffler. (McCord)

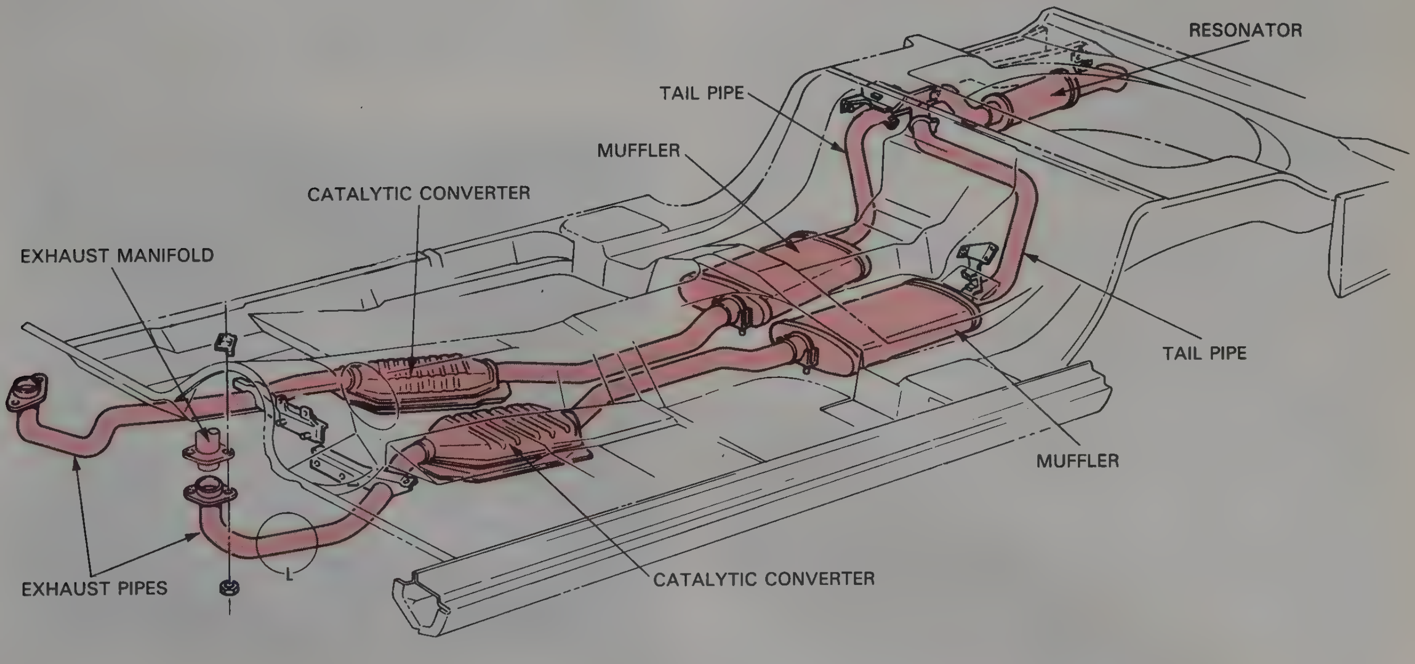

RESONATOR
TAIL PIPE
MUFFLER
CATALYTIC CONVERTER
EXHAUST MANIFOLD
TAIL PIPE
MUFFLER
EXHAUST PIPES
L
CATALYTIC CONVERTER

Fig. 35-6. Typical dual exhaust system. Note catalytic converters. (Chrysler)

The straight-through muffler design is illustrated in Fig. 35-8. As the name implies, the exhaust gas travels in one end, straight through, and out the other. The single, perforated pipe is surrounded with two layers of Fiberglas to effectively dampen the sound.

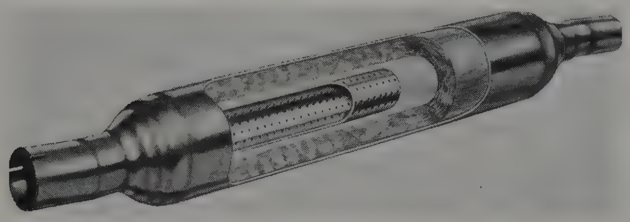


Fig. 35-8. Straight-through muffler design. Note layers of Fiberglas. (Walker)

The chambered pipe design, as shown in Fig. 35-9, controls exhaust sound with a minimum of bulk.

Mufflers may be ceramic coated steel, aluminized (coated with aluminum) steel, or made partially or completely of stainless steel to insure long life.

Exhaust and tail pipes may be aluminized steel, using single or double-wrap construction. The double wrap is more effective in reducing exhaust noise resulting from system pulsations.

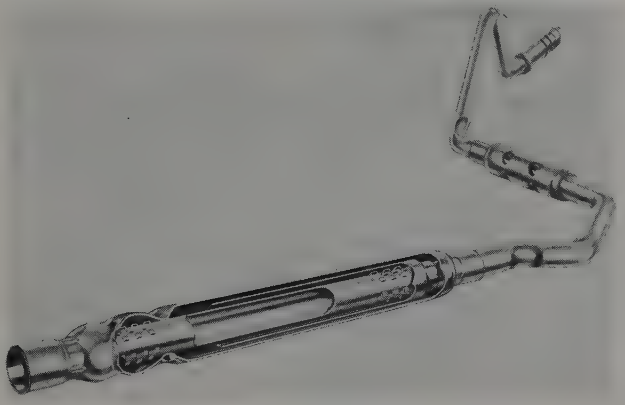


Fig. 35-9. Chambered pipe exhaust muffling system.

USE PROPER EXHAUST SYSTEM TOOLS

Exhaust system service is highly competitive. To show a profit, the work must be done swiftly, yet efficiently. To accomplish this, it is essential that proper tools be available.

The power chisel, with suitable cutter heads, is useful in cutting welded mufflers free and in removing tail and exhaust pipes. Note the assortment of cutting heads with the chisel in Fig. 35-10.

A hand pipe cutter, illustrated in Fig. 35-11, can be very helpful.

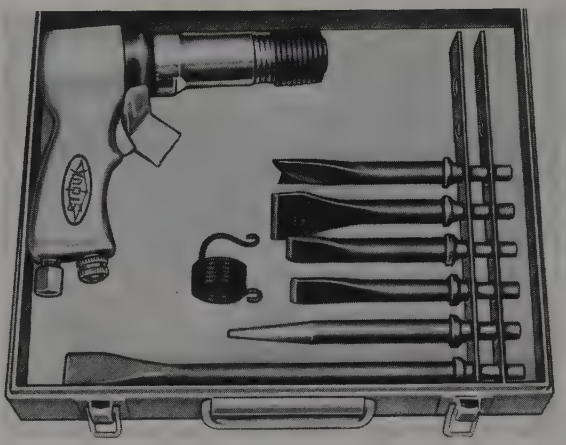


Fig. 35-10. Power chisel with assorted cutting heads. (Sioux)

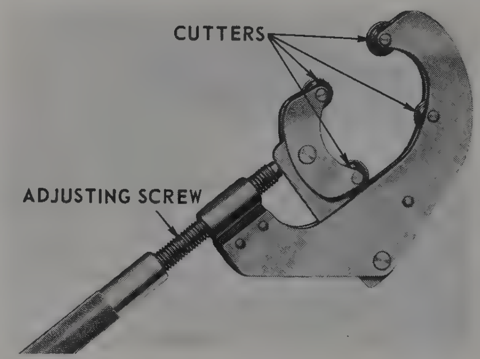


Fig. 35-11. Hand operated pipe cutter. (Walker)

Heat, applied to an exhaust system joint, can be effective in loosening the connection. An electric pipe joint heater (eliminates danger of using an open flame under car) is pictured in Fig. 35-12.

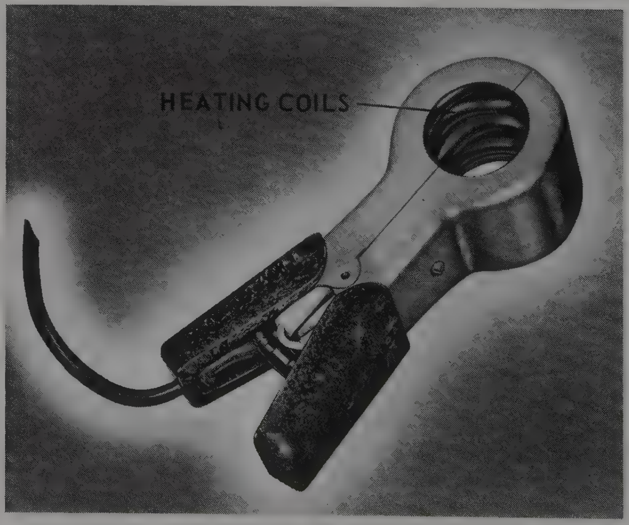


Fig. 35-12. Electric pipe joint heater.

Often pipes must be expanded to provide proper joint fit. This is easily done with a pipe expander. One is shown in Fig. 35-13.

The pipe end is often crimped or otherwise distorted. It may be readily brought back to a round shape by using the straightening cone shown in Fig. 35-14.

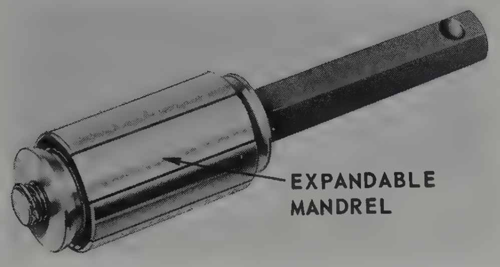


Fig. 35-13. Pipe expanding tool.

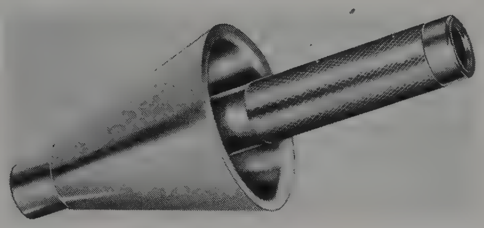


Fig. 35-14. Pipe end straightening cone. Cone is placed in deformed pipe end and tapped until pipe is round.

A chain wrench provides a way of both pulling and twisting a pipe to free the joint or to provide proper alignment. Fig. 35-15 pictures one type of chain wrench.

EXHAUST SYSTEM CLAMPS AND SUPPORT BRACKETS

It is important that the various parts of the exhaust system be properly joined and supported. Joint clamps and support brackets of many types are used. Fig. 35-16 shows a random sampling.

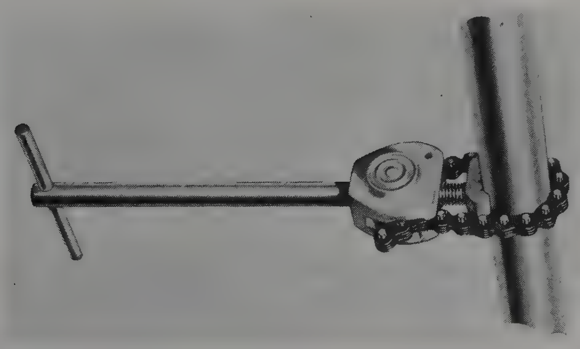


Fig. 35-15. Chain wrench provides a good grip on pipe to facilitate removal or alignment. (Walker)

Always use good clamps, of the proper size, to insure a good joint. Check support bracket flexible straps for breakage. Replace as needed, Fig. 35-17.

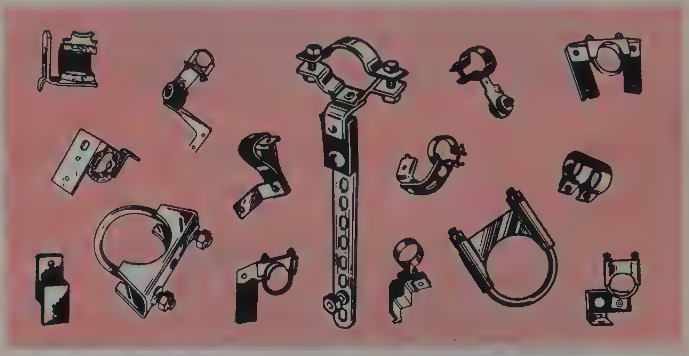


Fig. 35-16. Some typical clamp and support brackets. (McCord)

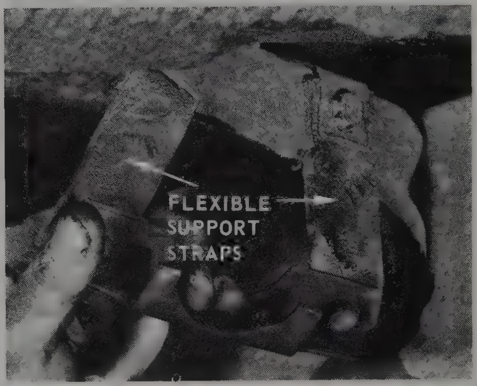


Fig. 35-17. Check condition of system support brackets. (Walker)

TAIL PIPE REMOVAL AND INSTALLATION

Raise the car. A frame contact hoist is perhaps the handiest type. It allows the rear axle to hang down, thus providing ample room for pipe removal.

USE PENETRATING OIL AND/OR HEAT

Apply penetrating oil to the tail pipe bracket fasteners and to the muffler outlet joint clamp. See Fig. 35-18.

Remove clamp and bracket fasteners. A power wrench, as in Fig. 35-19, speeds up this job.

Apply penetrating oil and tap outlet joint. Apply heat if needed. Pull tail pipe free with a chain wrench, Fig. 35-20.

If the tail pipe remains stuck in the muffler, cut the

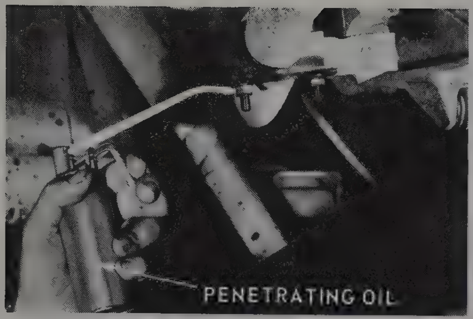


Fig. 35-18. Use penetrating oil to facilitate fastener removal.

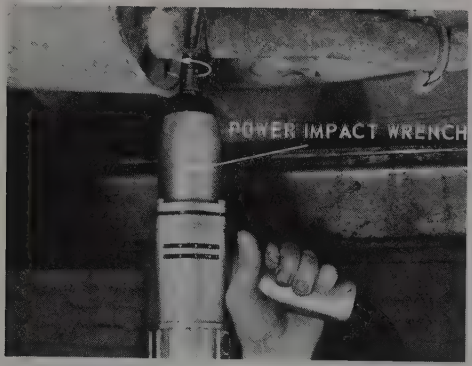


Fig. 35-19. Removing muffler outlet joint clamp nuts with a power wrench.

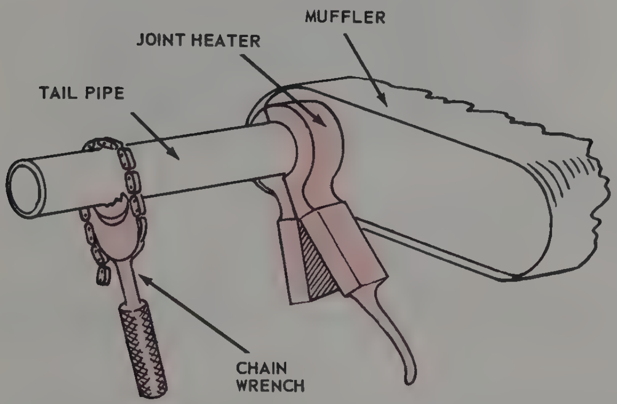


Fig. 35-20. Using heat and a chain wrench to free tail pipe from muffler.

pipe off just clear of the muffler outlet nipple. Look at Fig. 35-21.

Use power chisel and split section of tail pipe remaining in the nipple. Remove split section with pliers.

CLEAN MUFFLER NIPPLE

Clean the inside or outside of the muffler outlet nipple. Use coarse emery cloth. If the nipple is distorted, use the pipe end straightening tool.

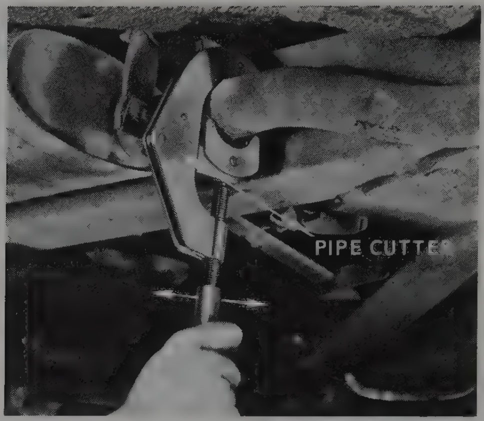


Fig. 35-21. Cutting tail pipe with hand pipe cutter.

USE EXHAUST SYSTEM SEALER

Apply a liberal coating of exhaust system sealer to the tail pipe where it will be in contact with the muffler nipple. Refer to Fig. 35-22.

Use exhaust sealer on all exhaust system joints. It makes the joints slide together easily, assists in alignment, and prevents dangerous exhaust leaks.

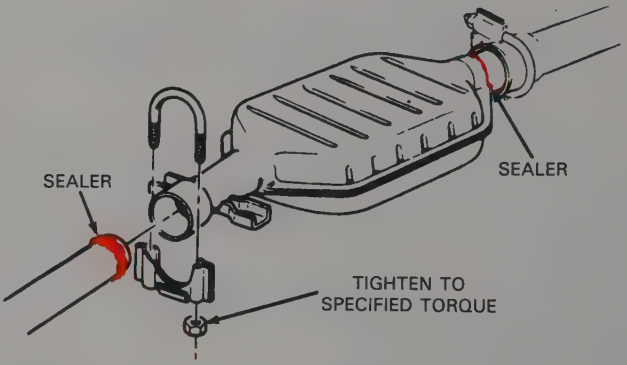


Fig. 35-22. Exhaust system sealer helps insure against leaking joints. Use proper sealer. (Chevrolet)

Some makers have designed special joints that are first assembled and then sealed. On setups requiring this technique, you must inject a special sealer into an annular ring or bead formed in the pipe. After injecting the sealant, idle the engine for around ten minutes to harden the compound. Fig. 35-23 illustrates this procedure.

PIPE (TAIL AND EXHAUST) DEPTH IN MUFFLER NIPPLE MUST BE CORRECT

When inserting the tail or exhaust pipe into the muffler, insert the pipe so it engages the full length of the nipple. See Fig. 35-24.

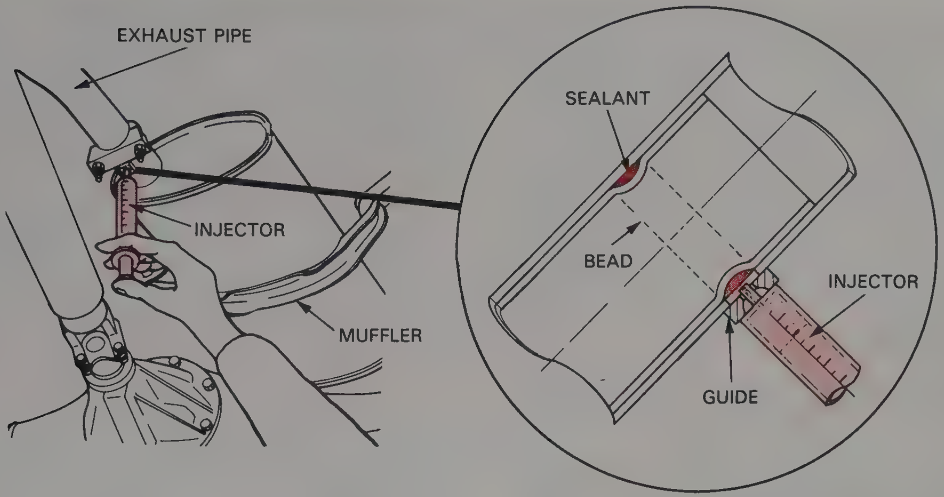

EXHAUST PIPE
INJECTOR
MUFFLER
SEALANT
BEAD
INJECTOR
GUIDE

Fig. 35-23. This exhaust system joint is designed to be assembled, tightened, THEN sealed by injecting sealer into an annular groove or bead. (Nissan)

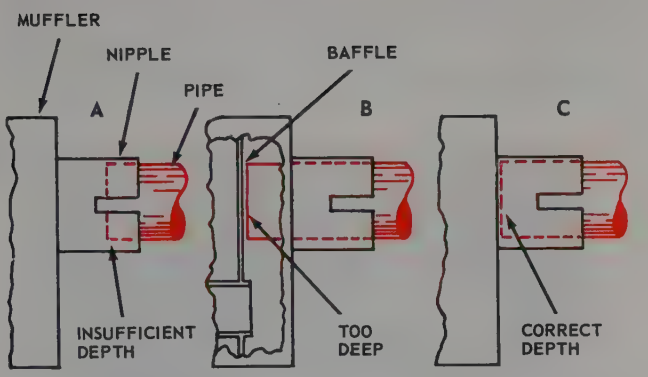

MUFFLER
NIPPLE
PIPE
A
BAFFLE
B
C
INSUFFICIENT DEPTH
TOO DEEP
CORRECT DEPTH

Fig. 35-24. A and B—Wrong. C—Pipe must enter muffler nipple to correct depth as shown.

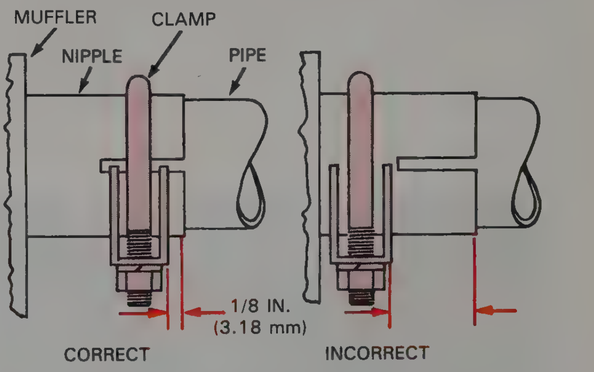

MUFFLER
CLAMP
NIPPLE
PIPE
1/8 IN.
(3.18 mm)
CORRECT
INCORRECT

Fig. 35-25. Retaining clamp should be positioned about 1/8 in. (3.18 mm) from end of nipple or pipe.

If the pipe enters too deep, it can cause back pressure. Insufficient contact will not allow proper clamping and will permit leakage or separation in service.

JOINT CLAMP MUST BE INSTALLED IN PROPER POSITION

Install the clamp so it is about 1/8 in. (3.18 mm) from the nipple end (or pipe end when pipe slips over nipple). Look at Fig. 35-25.

After aligning tail pipe, tighten clamp and brackets. Do not tighten clamp to the point the joint starts to collapse.

MUFFLER REMOVAL AND INSTALLATION

Remove tail pipe. If tail pipe is to be reused, use care during removal.

Remove muffler-to-exhaust pipe clamp. Use penetrating oil, tapping, and heat if required. Slit with chisel, if necessary. Pull muffler free.

Some mufflers are welded to the exhaust pipe. In such cases, cut off the exhaust pipe. Following cutting, straighten exhaust pipe end, Fig. 35-26.

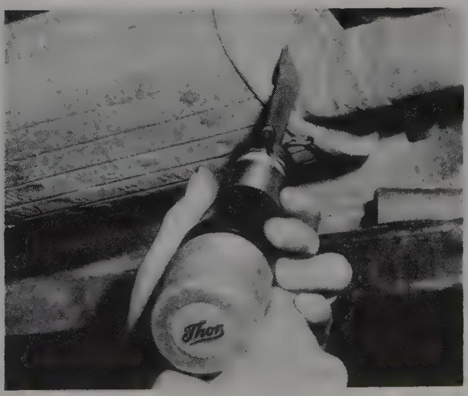


Fig. 35-26. Cutting muffler from exhaust pipe using a power chisel.

The replacement muffler will have a connection nipple that will engage the exhaust pipe.

Clean the end of exhaust pipe and apply exhaust sealer. Refer to Fig. 35-27.

Slide muffler inlet nipple and exhaust pipe together. Make certain depth is correct, Fig. 35-24. Slide clamp into position, Fig. 35-25, and tighten LIGHTLY. Muffler must be installed right side up and with the INLET connected to the EXHAUST pipe. See Fig. 35-28.

Install tail pipe. Align tail pipe and muffler. Tighten joint clamps and support brackets.

EXHAUST SYSTEM ALIGNMENT IS IMPORTANT

The alignment of the exhaust system is critical. It affects the clearances between various parts of the car and the exhaust system.

Make a careful check of the entire system to make certain that all parts have sufficient operating clearance. Pay particular attention to the tail pipe where it crosses over the rear axle. Make sure it clears the springs, shocks, and axle even though the springs may bottom under a heavy load or when hitting bumps.

The pipes must also clear the propeller shaft, brake lines, and gas lines.

Fig. 35-27. Using a strip of emery paper to clean exhaust pipe.

CHECK SYSTEM FOR LEAKS

AS A FINAL STEP, ALWAYS OPERATE THE ENGINE AND CHECK EACH JOINT FOR ANY SIGNS OF EXHAUST LEAKAGE. See Fig. 35-29. THE SYSTEM MUST BE AIR TIGHT TO PREVENT THE ESCAPE OF EXHAUST GASES.

EXHAUST GASES CONTAIN CARBON MONOXIDE (A DEADLY POISON) AND THEREFORE MUST NOT ESCAPE UNDER THE CAR. THEY COULD FLOW INTO THE VEHICLE'S PASSENGER COMPARTMENT.

IF A LEAK IS FOUND, REPAIR THE JOINT.

Fig. 35-30 shows some of the important considerations in exhaust system service: A—Use penetrating oil. B—Tighten clamps securely but not excessively. C—Slitting the joint makes pipe or muffler removal easy. D—Cut off the exhaust pipe when it is an integral part of the muffler. E—Clean all connections and use sealer. F—Use a new exhaust pipe-to-manifold gasket when this joint is disconnected. G—Muffler inlet must fit exhaust pipe. H—Muffler outlet must fit tail pipe. I—Align and tighten system. Check for leaks.

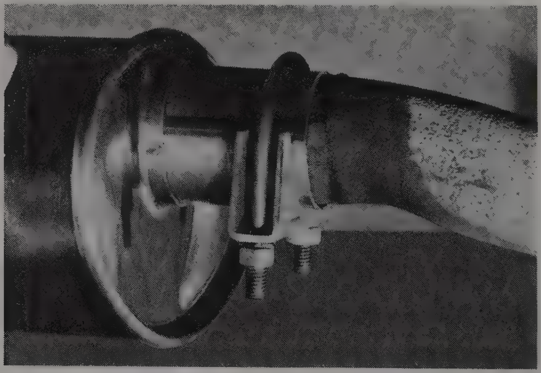


Fig. 35-28. New muffler installed on exhaust pipe. Note clamp positioning. (Walker)

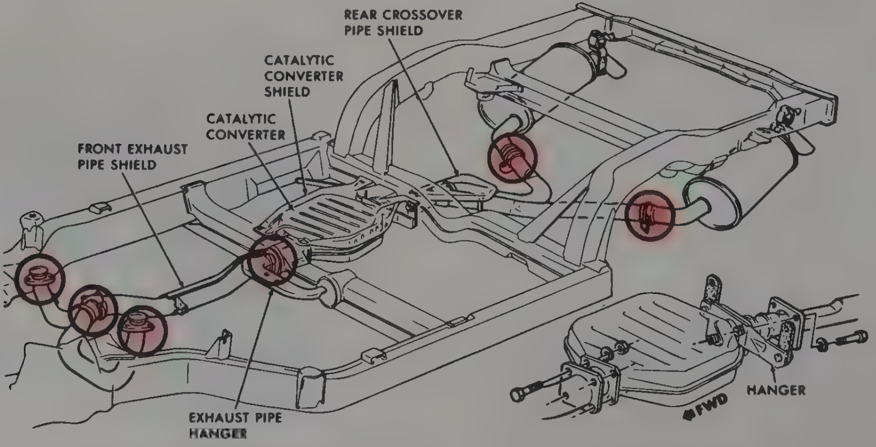

REAR CROSSOVER PIPE SHIELD
CATALYTIC CONVERTER SHIELD
CATALYTIC CONVERTER
FRONT EXHAUST PIPE SHIELD
EXHAUST PIPE HANGER
HANGER
FWD

Fig. 35-29. Check connections (circled areas) for leaks. (Chevrolet)

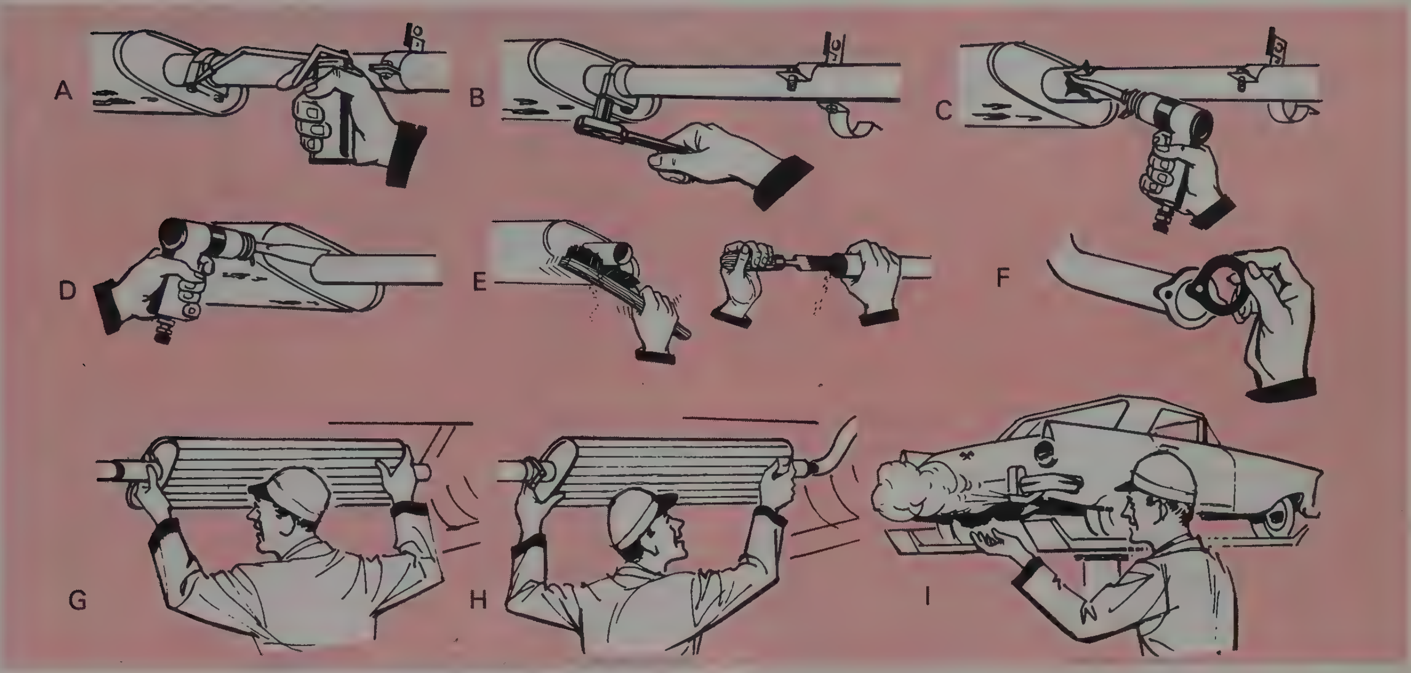


Fig. 35-30. Some important considerations in exhaust system service. (A. P. Parts Corp.)

MUFFLER AND PIPE SELECTION

Always use mufflers and pipes designed for the car at hand. NEVER USE UNDERSIZE PIPES OR MUFFLERS.

CATALYTIC CONVERTER INSTALLATION

Catalytic converters have, under proper operating conditions, a very long service life. Converter life is claimed to be 50,000 miles (80 000 km) or more, provided the catalyst is not exposed to lead or other damage.

When the converter is damaged by leaded fuel, excessively rich fuel mixture, or other problems, some permit the catalyst to be changed while the converter remains in place. Other models require replacement of the entire unit.

For instructions on catalyst replacement and for a detailed explanation of catalytic converter construction, operation, and cautions, refer to the section on converters in the emission control portion of this chapter.

Make certain all necessary heat shielding is in good condition and properly placed. Refer to Fig. 35-5.

EMISSION CONTROL SYSTEM SERVICE

When the exhaust valve opens, the fuel charge is still not completely burned. As a result, hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NOx) are released into the atmosphere. This produces a serious amount of air pollution.

To reduce the level of auto emissions, a number of emission controls have been developed. They are of three basic types: INTERNAL ENGINE, EXTERNAL ENGINE, and FUEL SYSTEM VAPOR CONTROLS.

The internal engine controls embrace such things as basic engine design (combustion chamber, camshaft, and intake manifold design) as well as all controls used to alter ignition timing, fuel mixture, engine temperature, and other variables. All of these are designed to offer a more complete burning of the fuel charge within the combustion chamber.

External controls are used to assure continued burning of the exhaust as it is forced out the exhaust valve and passes through the exhaust system. Major controls here are the AIR INJECTION system and the CATALYTIC CONVERTER.

The fuel system vapor controls are designed to eliminate the escape of gasoline fumes (vapor) from the tank filler cap, tank, carburetor, and other system components.

Also falling under vapor control is the control of engine crankcase fumes. This is accomplished by the POSITIVE CRANKCASE VENTILATION system.

POSITIVE CRANKCASE VENTILATION — OPERATION AND SERVICE

Positive crankcase ventilation is an emission control that utilizes engine vacuum to draw the crankcase fumes back into the cylinders for burning. This system is commonly called PCV.

A malfunctioning PCV system can produce serious engine problems: rough idle, oil loss, etc. Check system periodically. See page 873.

AIR INJECTION SYSTEM

The air injection system, known as AIR INJECTION REACTOR, THERMACTOR, AIR GUARD, etc., attacks the emissions problem by continuing the combustion process OUTSIDE the cylinder. This is accomplished by a belt-driven air pump and system of tubes or passages that routes a stream of fresh air into the exhaust just as it passes out the exhaust valve.

The fresh air provides sufficient oxygen to stimulate further burning of the exhaust gases. This additional burning reduces the amount of hydrocarbons and changes a sizable portion of the carbon monoxide (poisonous gas) into carbon dioxide (harmless gas). A schematic of one specific system is shown in Fig. 35-31. Study flow of air from air cleaner to exhaust valve port. Note that during deceleration, a controlled amount of air is fed into the intake manifold to lean out the rich mixture that tends to form during deceleration. This helps prevent "backfiring."

AIR INJECTION — AIR PUMP

The air pump is of the positive displacement, vane type. A belt, V-type or ribbed, drives the pump rotor, causing the vanes to rotate in the housing. Carbon shoes and springs in the rotor keep vanes aligned and permit a sliding movement between the vanes and rotor. The vanes pass very close to the housing to limit air leakage.

As the vanes rotate, each one in turn passes the intake chamber, Fig. 35-32, where a charge of air is drawn in. The vane that follows forces this air charge around into the compression chamber where the air volume is reduced. This places it under pressure. The pressurized air is then discharged through the exhaust chamber. The intake and exhaust chambers are separated by the stripper (section of housing). Fig. 35-32 shows pump action.

Pump maximum pressure is controlled by a pressure relief valve, which is located either in the pump housing or as part of the diverter valve. See Fig. 35-31.

Metering grooves in the housing wall (in both intake and exhaust chambers) quiet pump operation by providing a smoother transition from intake through exhaust. Fig. 35-33 shows an exploded view of an air pump.

PUMP INTAKE AIR IS FILTERED

The pump intake air is filtered either by drawing it from the carburetor air cleaner, through a special filter, Fig. 35-35, or by using a centrifugal filter. Centrifugal filter operation is pictured in Fig. 35-34.

CHECK VALVE

From the pump, the air flows through the diverter valve, through a hose, and on to a check valve. See Fig. 35-31. The check valve is forced off its seat by

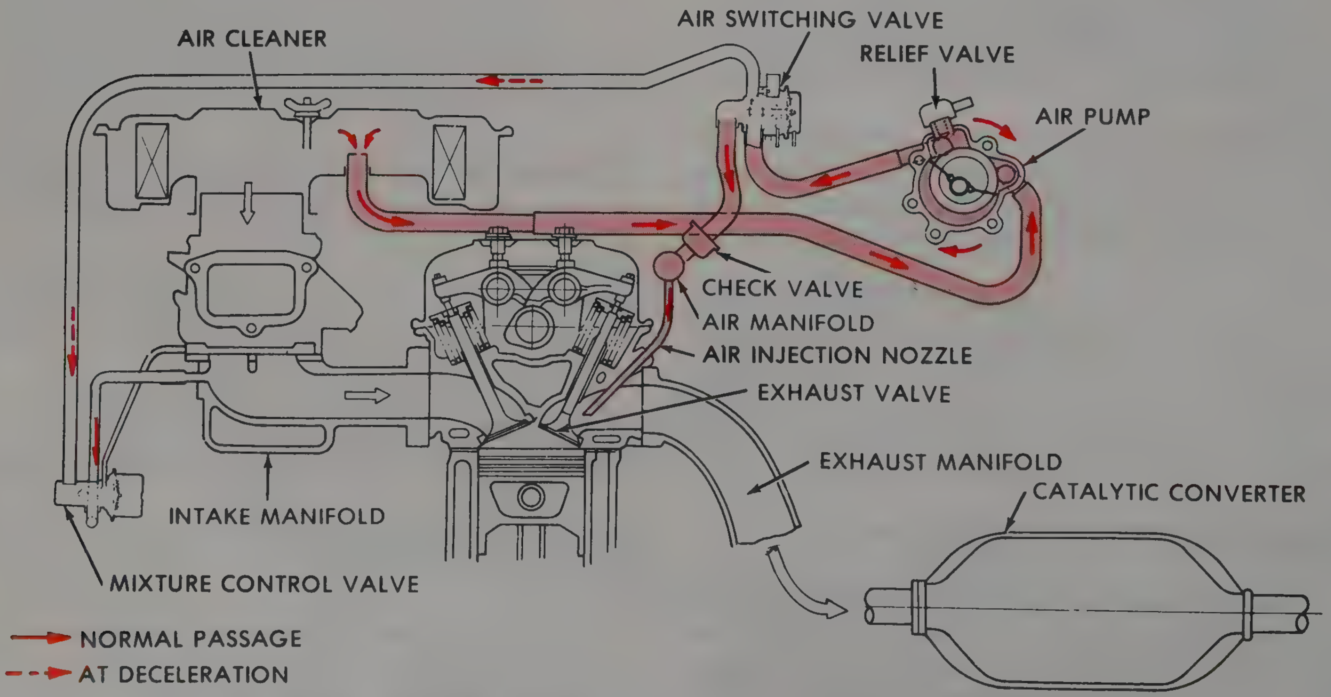
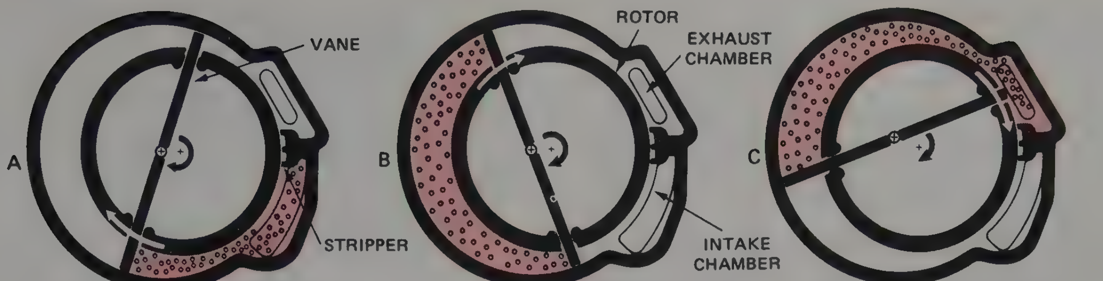


Fig. 35-31. Schematic showing typical air injection system. Air switching valve prevents backfires. (Chevrolet)


VANE
ROTOR
EXHAUST CHAMBER
A
B
C
STRIPPER
INTAKE CHAMBER

The vane is travelling from a small area into a larger area—consequently a vacuum is formed that draws fresh air into the pump.

As the vane continues to rotate, the other vane has rotated past the inlet opening. Now the air that has just been drawn in is entrapped between the vanes. This entrapped air is then transferred into a smaller area and thus compressed.

As the vane continues to rotate it passes the outlet cavity in the pump housing bore and exhausts the compressed air into the remainder of the system.

Fig. 35-32. Air pump operation. Note how vanes function. A—Drawing in air. B—Moving air around. C—Compressing and exhaust air.

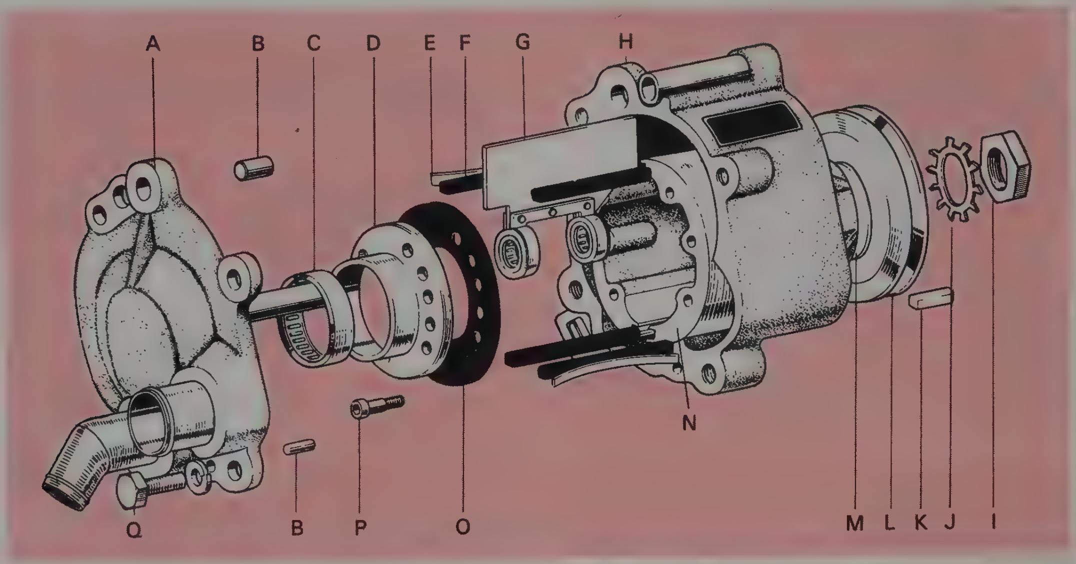

A
B
C
D
E
F
G
H
N
Q
B
P
O
M
L
K
J
I

Fig. 35-33. Exploded view of one type of air injection system pump. A—End cover. B—Dowel. C—Bearing. D—Rotor ring. E—Shoe spring. F—Carbon shoe. G—Vane. H—Housing. I—Lock nut. J—Lock washer. K—Key. L—Pulley. M—Pulley plate. N—Rotor. O—Rear seal. P—Rotor ring screw. Q—Cover bolt. (Toyota)

pump air pressure, thus allowing the air to enter the distribution manifold.

In the event the pump should fail, or if exhaust pressure exceeds pump pressure, the check valve returns to its seat. This prevents the exhaust gases from flowing through the hose to the pump.

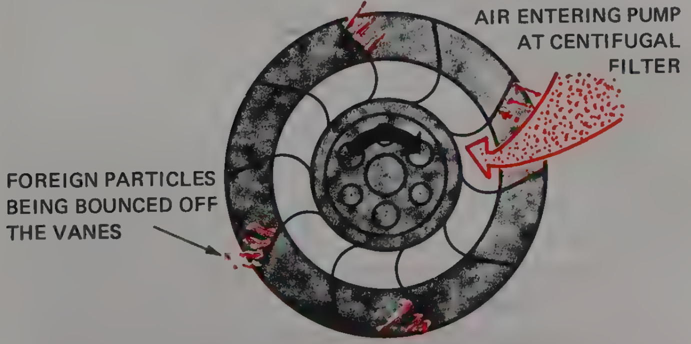

AIR ENTERING PUMP AT CENTIFUGAL FILTER
FOREIGN PARTICLES BEING BOUNCED OFF THE VANES

Fig. 35-34. Centrifugal air filter spins at high speed and throws foreign particles outward by means of whirling vanes. (Chevrolet)

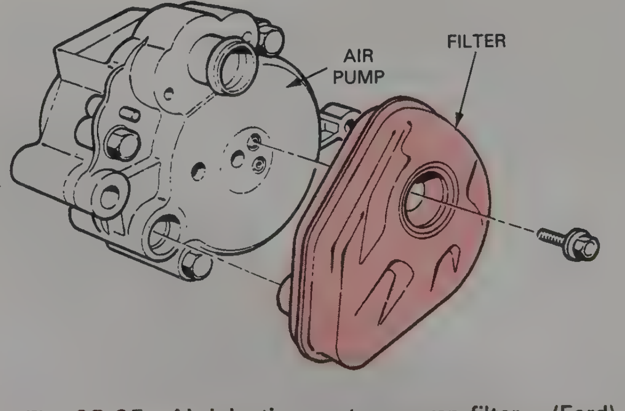

AIR PUMP
FILTER

Fig. 35-35. Air injection system pump filter. (Ford)

DISTRIBUTION MANIFOLD AND AIR INJECTION TUBES

From the check valve, the air enters the distribution manifold. From the manifold, the air flows through the air injection tubes. It then enters the exhaust gas near the exhaust valve.

As mentioned, the air provides enough oxygen to stimulate further burning of the exhaust gases. This reduces the hydrocarbon and carbon monoxide emission levels.

Fig. 35-36 shows one type of air injection arrangement used on a V-8 engine.

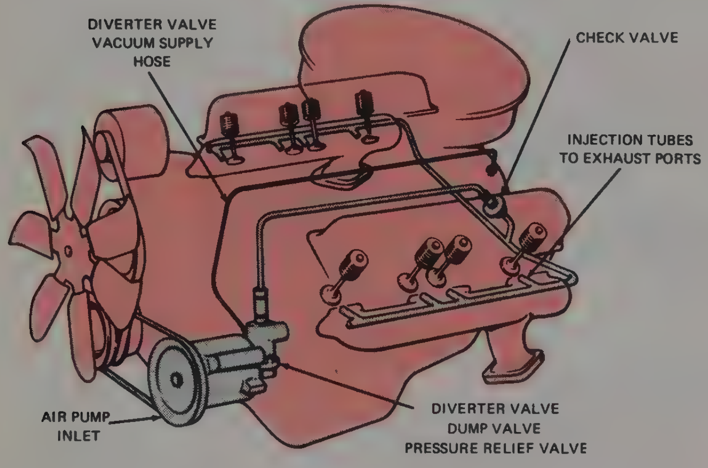

DIVERTER VALVE VACUUM SUPPLY HOSE
CHECK VALVE
INJECTION TUBES TO EXHAUST PORTS
AIR PUMP INLET
DIVERTER VALVE DUMP VALVE PRESSURE RELIEF VALVE

Fig. 35-36. One air injection setup used on V-8 engines. (Dodge)

DIVERTER VALVE PREVENTS BACKFIRE

When the carburetor throttle valve is closed quickly, gasoline momentarily continues to flow. Since little or no air is entering the engine during this period, the flow of gasoline produces a rich mixture. It will leave a considerable amount of unburned gas following the power (combustion) stroke.

This gas-laden exhaust mixture, when it passes exhaust valve and strikes injected stream of air, will begin to burn again with explosive force. This causes a "backfire."

The diverter valve is designed to momentarily divert the air stream from the diverter valve to the injection nozzles. It does this by means of a vacuum diaphragm or electrically controlled metering valve. See Fig. 35-37.

Diverter valve action is shown in Fig. 35-38. In detail A, airflow is passing through the diverter valve and on to the air injectors.

When the throttle is suddenly released, heavy intake manifold vacuum is applied to the metering valve control diaphragm. The diaphragm is drawn downward, forcing the metering valve to block off passage to the air injection manifold. This downward movement opens up the diverter passage and pump air is momentarily discharged into the atmosphere. See detail B in Fig. 35-38.

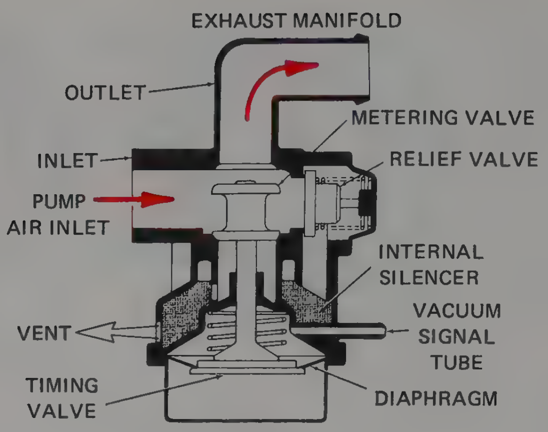

EXHAUST MANIFOLD
OUTLET
METERING VALVE
INLET
RELIEF VALVE
PUMP AIR INLET
INTERNAL SILENCER
VACUUM SIGNAL TUBE
VENT
TIMING VALVE
DIAPHRAGM

Fig. 35-37. Typical diverter valve, which is also called an anti-backfire valve. (Cadillac)

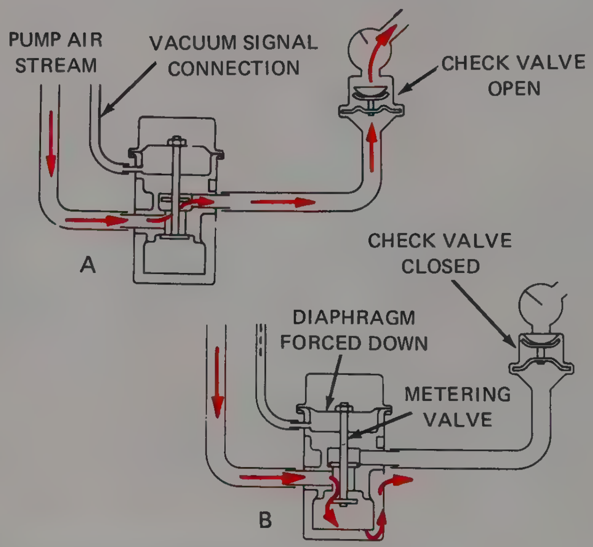

PUMP AIR STREAM
VACUUM SIGNAL CONNECTION
CHECK VALVE OPEN
A
CHECK VALVE CLOSED
DIAPHRAGM FORCED DOWN
METERING VALVE
B

Fig. 35-38. Diverter valve action. A—Valve in normal position. B—During deceleration, air is diverted into atmosphere. (Toyota)

AIR CONTROL VALVE

Some air injection emission control setups use an air control valve on their air management systems. The valve can be made as an integral, combination unit or as separate valves, each performing a specific function.

The air control valve can be used to perform the normal diverter valve functions. It can also be used for channeling pump air to the intake manifold, exhaust manifold, or to the catalytic converter, as determined by system needs. Fig. 35-39 shows one air control valve that, during engine warmup, channels pump air to the

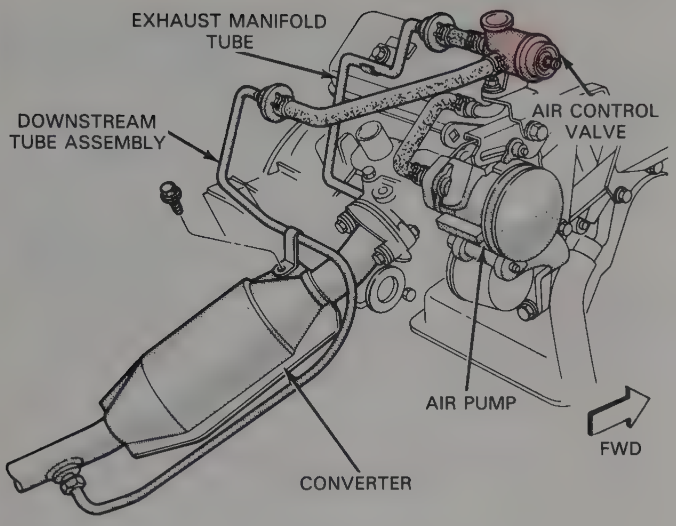

EXHAUST MANIFOLD TUBE
DOWNSTREAM TUBE ASSEMBLY
AIR CONTROL VALVE
AIR PUMP
FWD
CONVERTER

Fig. 35-39. Air control valve on this setup directs pump air to exhaust manifold when engine is cold and to exhaust pipe, through downstream tube, when hot. (Chrysler)

exhaust port area. Then, when normal operating temperature is reached, it diverts the air to the catalytic converter.

A cross-sectional view of another type air control-combination valve is pictured in Fig. 35-40. Study valve construction and note various air channels.

PULSE TYPE AIR PUMP SYSTEM

One air injection system utilizes the pulse effect of the engine exhaust to pull air into the exhaust manifold. Small "gulps" of air are drawn in through the check valves. See Fig. 35-41. The manufacturer refers to this as the Pulsair Injection Reaction System.

Another adaptation of the pulse principle is illustrated in Fig. 35-42. The crankcase area of the number three engine cylinder is baffled so that the reciprocating action of the piston causes pressure pulsations. These pulsations cause the diaphragm in the pulse air feeder to move up and down. This action pulls air in from the air cleaner and then forces it out and on to the converter area. Study the system construction. Note the oil drain line that allows any oil collected in the pulse air feeder to return to the pan sump.

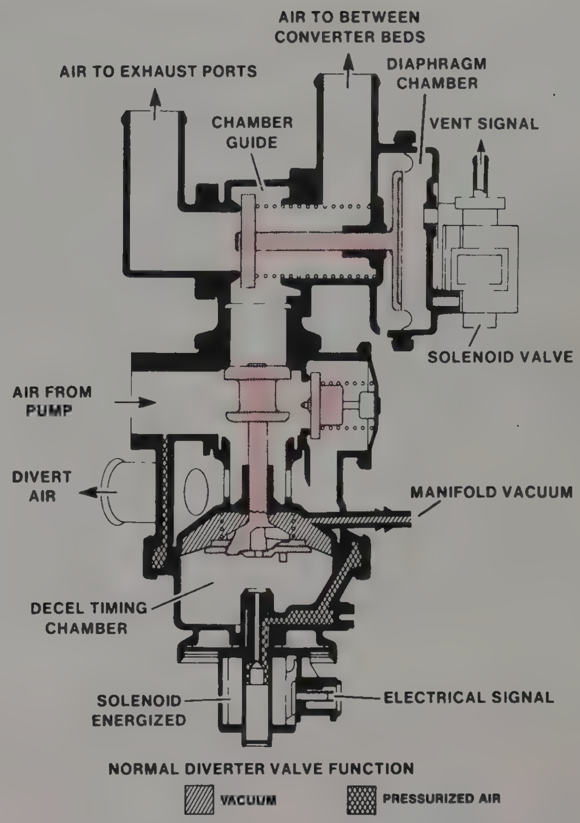

AIR TO BETWEEN CONVERTER BEDS
AIR TO EXHAUST PORTS
DIAPHRAGM CHAMBER
CHAMBER GUIDE
VENT SIGNAL
SOLENOID VALVE
AIR FROM PUMP
DIVERT AIR
MANIFOLD VACUUM
DECEL TIMING CHAMBER
SOLENOID ENERGIZED
ELECTRICAL SIGNAL
NORMAL DIVERTER VALVE FUNCTION
▨ VACUUM
▩ PRESSURIZED AIR

Fig. 35-40. This air control valve is in DIVERT mode. It is controlled both by vacuum and electrical signals. Note exhaust port and converter air outlets. (Chevrolet)

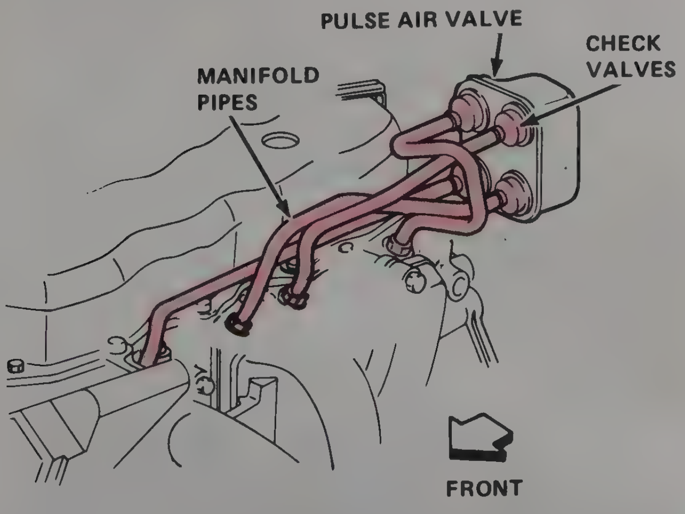

PULSE AIR VALVE
CHECK VALVES
MANIFOLD PIPES
FRONT

Fig. 35-41. Air injection system using PULSE principle. Pulses in exhaust pull air in through check valves in small gulps. (GMC)

AIR INJECTION SYSTEM SERVICE — AIR CLEANER

When the air pump intake is by way of the carburetor air cleaner, normal cleaner maintenance will suffice.

In cases where a special filter is used, replace the filter at recommended intervals. Under adverse conditions, change it more often. When installing a new filter, wipe off filter body and air horn assembly.

AIR PUMP

The air pump has sealed bearings, so periodic maintenance is not required.

Drive belt tension is important and should be as specified. A loose belt will reduce pump efficiency. A tight belt will cause premature wear of the pump bear-

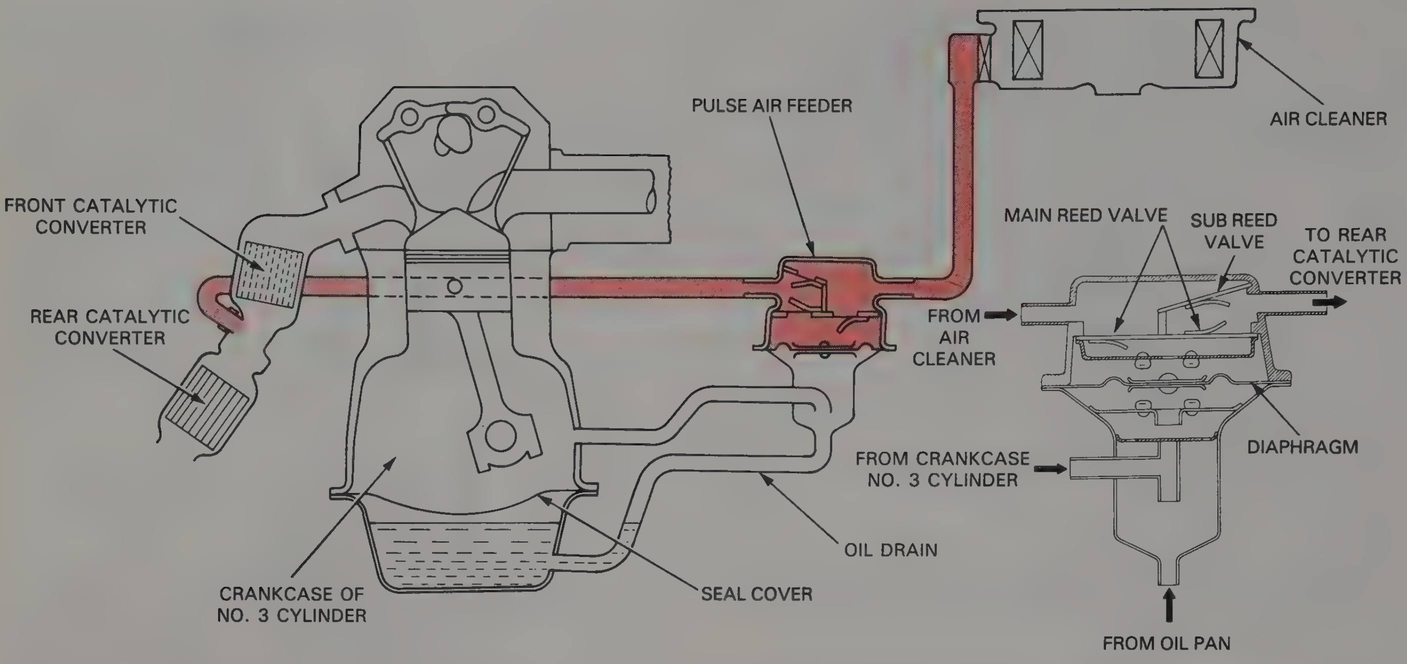


Fig. 35-42. Another system using pulse principle. In this case, pulses are formed in number three cylinder crankcase area. Piston movement in this baffled area causes pulse in crankcase pressure that operates pulse air feeder. Feeder, much like action of fuel pump, pumps air from cleaner into exhaust stream. (Chrysler)

ings. When adjusting the belt, avoid prying on the soft, die cast pump housing. Pull on the pump with your hand only or use a built-in adjustment slot or pin where provided. Use a reliable gauge to tension belt properly.

To check the pump for operation, remove the outlet hose at the pump. Start the engine. A discharge of air at the pump outlet should be evident. A special low pressure gauge may be used to check pump pressure. Pressure will be about 1.0 psi (6.9 kPa).

If the pump is not producing sufficient pressure, check the air filter for clogging. When difficulty is experienced with the pump relief valve, remove the pump and install a new valve.

If a pump seems noisy, remove the drive belt and retest. Keep in mind that air pumps are not completely silent even when in perfect condition.

CHECK VALVE

Remove the hose from the valve. Start the engine and operate at 1500 rpm. There should be no sign of exhaust leakage. When the engine is idled, the valve may flutter. This condition is normal.

With the engine off, use a thin instrument to press against the valve plate. It should open readily and return to its original position when released.

Check both valves on V-type engines. Replace as needed.

ANTI-BACKFIRE (DIVERTER VALVE)

Check lines (especially vacuum signal line) for kinks, pinches, or leaks. Remove vacuum signal line at valve. With engine running, a vacuum signal must be present.

With engine running at idle, no air should be diverted. When the throttle is opened up, then quickly released, a sudden gust of air should be discharged into the atmosphere.

If the anti-backfire valve is defective, replace it.

DO NOT USE AIR PRESSURE ON VALVES

Never try to clean the anti-backfire valves or check valves by using compressed air. This can ruin the valve. If dirty, flush valve with solvent and shake dry.

DISTRIBUTION MANIFOLD AND AIR INJECTION TUBES

The distribution manifold and air injection tubes do not require periodic maintenance. They are usually made of stainless steel. If the injection tubes become burned, they may be replaced. If the tubes are clogged, they may be cleaned with a wire brush.

If the distribution manifold needs cleaning, use regular cleaning methods and solvents.

HOSES

Check the hose system for loose connections, kinks, or other damage. Repair or replace as needed. Typical hose routing is pictured in Figs. 35-31 and 35-36.

Soapy water may be placed on the hose or hose connections. If an air leak exists, bubbles will form.

ENGINE SHOULD BE AT OPERATING TEMPERATURE

The engine should be brought to operating temperature BEFORE conducting air injection system tests. Hoses should also be checked for leaks and possible restrictions.

EXHAUST GAS RECIRCULATION

When the temperature of the burning fuel mixture exceeds around 2,500°F (1 372°C), nitrogen in the air tends to mix with the oxygen. This forms NOx (nitrous oxides, also called oxides of nitrogen).

By recirculating a portion of the burned exhaust gas back into the intake manifold, the peak flame temperature in the cylinders is lowered. This provides a significant reduction in the amount of NOx produced.

The amount of exhaust gas fed into the intake manifold is automatically controlled by the exhaust gas recirculation (EGR) valve. During idle and wide open throttle conditions, the EGR valve remains closed. There are five basic types of EGR valves including: integrated electronic valves, digital valves, ported valves, positive back pressure valves, and negative back pressure valves. These valves are operated by engine vacuum, and/or electrical signals.

INTEGRATED ELECTRONIC EGR VALVE

The integrated electronic EGR valve uses engine vacuum and electrical signals to control EGR flow. This valve contains a voltage regulator, which modifies ECU signals and regulates current to a solenoid. The ECU helps control EGR flow using a modulated signal (modified pulse width) based on airflow, throttle position, and engine speed. A pintle position sensor is also used in an integrated electronic EGR valve. As EGR flow increases, the pintle position sensor's output increases. See Fig. 35-43.

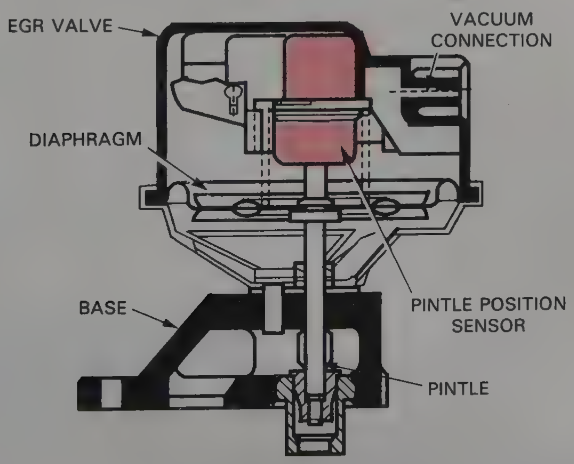


Fig. 35-43. Cutaway view of an integrated electronic EGR valve. Note the pintle position sensor. (Sun Electric)

DIGITAL EGR VALVE

The digital EGR valve functions without engine vacuum. EGR flow passes through three orifices, which are opened and closed by electric solenoids. The solenoids are controlled by the electronic control unit. When the solenoids are energized, the armature rises and the pintle is lifted from its seat. The ECU uses input signals from the throttle position sensor (TPS), coolant temperature sensor, and the mass airflow sensor to calculate the proper orifice openings. This valve usually operates above idle and during warm engine operating conditions. A digital EGR valve is shown in Fig. 35-44.

PORTED EGR VALVE

Fig. 35-45 illustrates ported EGR valve action. A spring-loaded diaphragm is used to keep the valve closed. When the vacuum port is uncovered, the diaphragm is forced upward and the valve is opened.

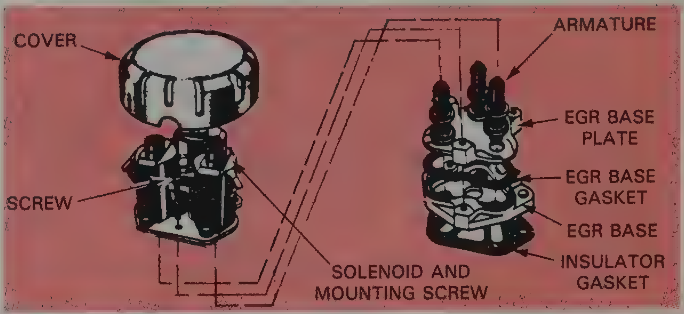


Fig. 35-44. Exploded view of a digital EGR valve. Follow manufacturer's recommendations when servicing this unit. (Sun Electric)

In A, vacuum is low and the spring keeps valve closed. In B, increased vacuum has pulled the valve upward to pass burned exhaust gases back into the intake manifold.

POSITIVE BACK PRESSURE TRANSDUCER VALVE

Some EGR valves use an exhaust back pressure transducer valve (BPV) to modulate the amount of vacuum operating on the EGR valve diaphragm. BPV is a device that utilizes power from one source to provide control of another power or action.

One example of the positive back pressure valve is illustrated in Fig. 35-46. Note that the transducer is incorporated into the valve. In A, exhaust gas cannot flow to the intake manifold but can create a pressure on the transducer diaphragm. Pressure is low and the spring control valve remains open. This allows air to flow through bleed holes in the diaphragm plate, past the diaphragm, and through the spring control valve. This weakens vacuum in the vacuum chamber and the

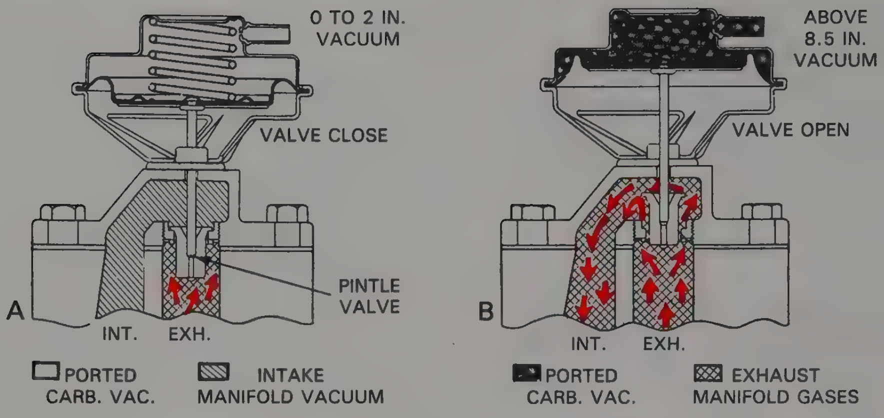

0 TO 2 IN.
VACUUM
VALVE CLOSE
PINTLE
VALVE
A
INT.
EXH.
☐ PORTED
CARB. VAC.
▨ INTAKE
MANIFOLD VACUUM
ABOVE
8.5 IN.
VACUUM
VALVE OPEN
B
INT.
EXH.
■ PORTED
CARB. VAC.
▩ EXHAUST
MANIFOLD GASES

Fig. 34-45. Ported EGR valve action. A—Low vacuum signal, valve is closed. B—High vacuum signal, diaphragm opens valve. (Oldsmobile)

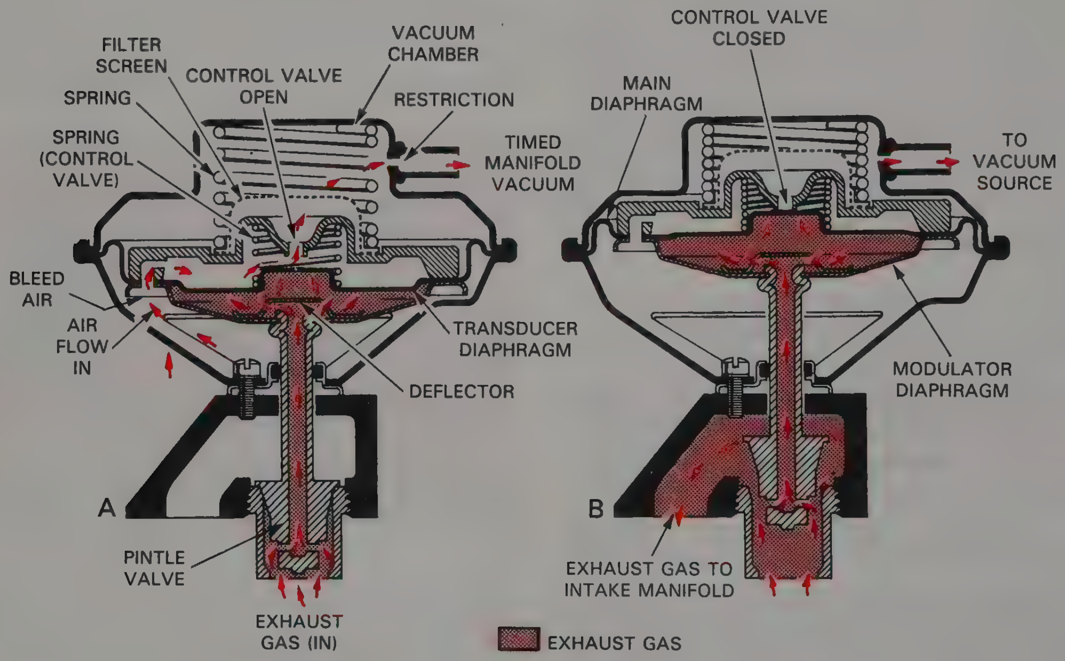

FILTER
SCREEN
SPRING
SPRING
(CONTROL
VALVE)
CONTROL VALVE
OPEN
VACUUM
CHAMBER
RESTRICTION
TIMED
MANIFOLD
VACUUM
BLEED
AIR
AIR
FLOW
IN
TRANSDUCER
DIAPHRAGM
DEFLECTOR
A
PINTLE
VALVE
EXHAUST
GAS (IN)
CONTROL VALVE
CLOSED
MAIN
DIAPHRAGM
TO
VACUUM
SOURCE
MODULATOR
DIAPHRAGM
B
EXHAUST GAS TO
INTAKE MANIFOLD
▩ EXHAUST GAS

Fig. 35-46. Internally modulated EGR valve. A—Control valve is open, EGR valve is closed. B—Exhaust back pressure closes control valve, causing EGR valve to open. (Chevrolet)

main diaphragm will not draw the exhaust gas recirculation valve open.

In B, Fig. 35-46, exhaust back pressure has built up, shoving the transducer diaphragm upward. This closes the control valve and stops air flow into the vacuum chamber. As a vacuum is no longer weakened by bleed air, the main diaphragm rises and opens the valve. This permits flow of gases to the intake manifold.

This type of EGR valve will not open if test vacuum is applied with the engine OFF.

NEGATIVE BACK PRESSURE VALVE

A negative back pressure EGR valve is pictured in Fig. 35-47. You will note that in this setup, the bleed valve spring is located below the diaphragm. In this position, the spring holds the diaphragm against the air bleed hole, keeping it CLOSED.

As soon as engine vacuum is applied to the EGR valve, the diaphragm will be forced upward, opening the valve. It then passes a metered quantity of exhaust into the intake manifold.

With NEGATIVE exhaust back pressure, the central diaphragm area is pulled down against pressure of the small spring. The bleed hole is then exposed, lowering the effect of engine vacuum. This causes the heavy top spring to force the main diaphragm downward, closing the valve.

The negative backpressure valve will open if test vacuum is applied with engine off. Look at Fig. 35-47.

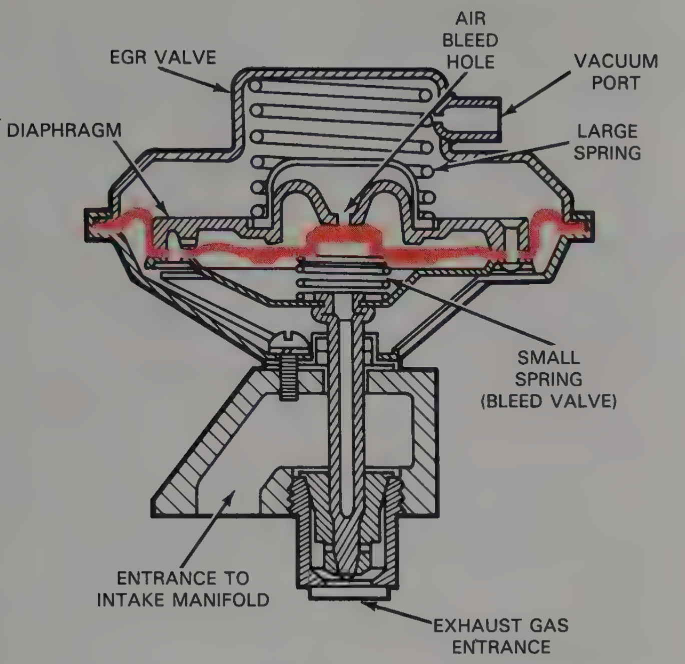


Fig. 35-47. Negative pressure EGR valve. Note location of bleed valve spring. (Buick)

TESTING EGR VALVE

When testing the EGR valve, the test technique should conform to the valve type at hand. Test valve action with the engine at operating temperature, unless checking action of a thermal vacuum switch.

Depress, when possible, the EGR diaphragm with the tip of your fingers. If the engine was idling smoothly, it should immediately lose about 200 rpm and show signs of roughness. If this happens, the EGR valve is all right so far.

If no loss in rpm is evident and if engine operation is smooth, the passage between the EGR valve and the intake manifold may be plugged. Remove and clean passageway and EGR valve.

If no loss in rpm is evident and if engine idle is rough, the valve may be admitting exhaust gases all the time. This indicates a faulty valve or improper hose routing.

Place a "T" in the vacuum signal line and attach a vacuum gauge. Run up engine rpm and note vacuum reading when diaphragm starts to move. Valve opening should fall within specified limits.

When replacing an EGR valve, if a restrictor plate is used, make certain it is in place. If replacement is necessary, use CORRECT size. Make certain new valve is of proper type.

NEVER DISCONNECT OR RENDER THE EGR VALVE INOPERATIVE ON A PERMANENT BASIS. To do so will cause emission levels to rise. This is against the law. In addition, many engines will run hotter and in some cases, detonate to the point of serious engine damage (burned valves and pistons).

CLEANING THE EGR VALVE

Some EGR valves may be disassembled for cleaning. On those that are not, the open end of the pintle valve may be rapped with a plastic hammer to break loose any carbon accumulation. A brush may also be used to assist cleaning. Do NOT sandblast an EGR valve.

NEVER SOAK OR WASH AN EGR VALVE IN CLEANING SOLVENT. This could seriously damage the diaphragm.

One type of cleanable EGR valve is shown in Fig. 35-48. This type of valve should be cleaned approximately once every three years or 30,000 miles (48 000 km).

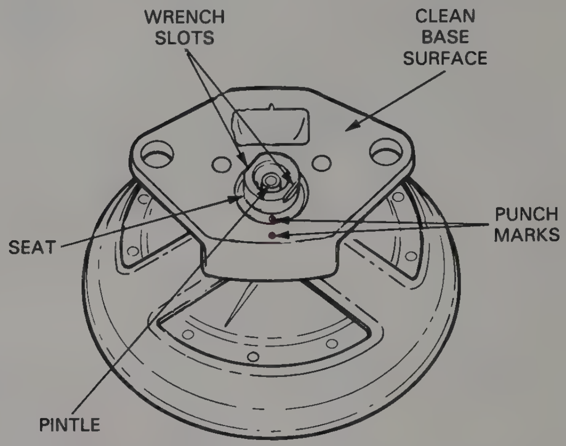


Fig. 35-48. Before disassembling this cleanable EGR valve, make certain there are punch marks and that they are aligned. (Buick)

General steps in disassembly and cleaning are given in Fig. 35-49.

Clean off any gasket material and check for the two punch marks. These marks will insure proper alignment upon reassembly. See Fig. 35-48.

Measure the distance from the base to the shoulder as shown in A, Fig. 35-49. Note this distance because it must be established again during reassembly.

With a properly fitting wrench, remove the seat, B, Fig. 35-49. A small amount of penetrating oil on the threads will ease removal. Do not allow penetrating oil to foul diaphragm.

After pintle seat is removed, grasp pintle (not on sealing surface). With valve in an upright position, pull pintle downward, as in C.

Using the specified size drill bit, turn drill (clockwise) up into shaft. Go in a short distance (about an inch) and withdraw to clear drill of carbon. Continue until drill passes through shaft hole. Rap base to jar out any loose particles, D, Fig. 35-49.

Brush and shake valve. If air is used, DO NOT direct

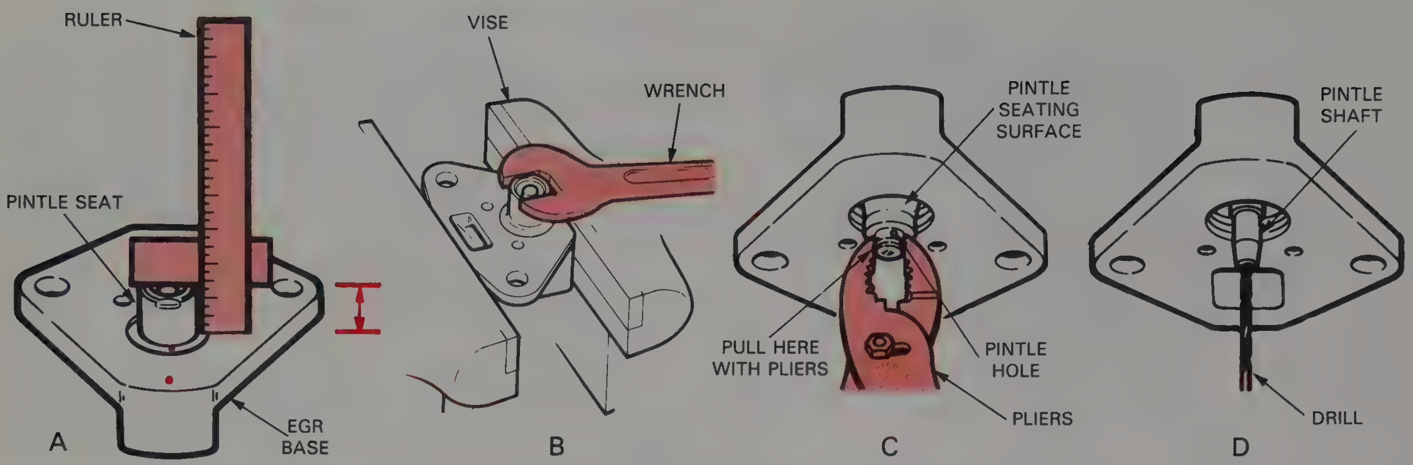

RULER
PINTLE SEAT
EGR BASE
A
VISE
WRENCH
B
PINTLE SEATING SURFACE
PULL HERE WITH PLIERS
PINTLE HOLE
PLIERS
C
PINTLE SHAFT
DRILL
D

Fig. 35-49. Steps involved in disassembly of this EGR valve. A—Check height of pintle seat shoulder-to-base. B—Remove pintle seat. C—Pull pintle from shaft. D—Clean carbon from hollow shaft with appropriate drill bit. (Buick)

air into the shaft opening.

Replace pintle on shaft and force down until it snaps into place. Reinstall base. Thread in to original height and make sure punch marks are aligned. Using a prick punch, restake seat. Using a new gasket, reinstall EGR valve.

DIESEL ENGINE EGR VALVE

An EGR valve setup as used on a V-type diesel engine is illustrated in Fig. 35-50. Note use of vacuum pump.

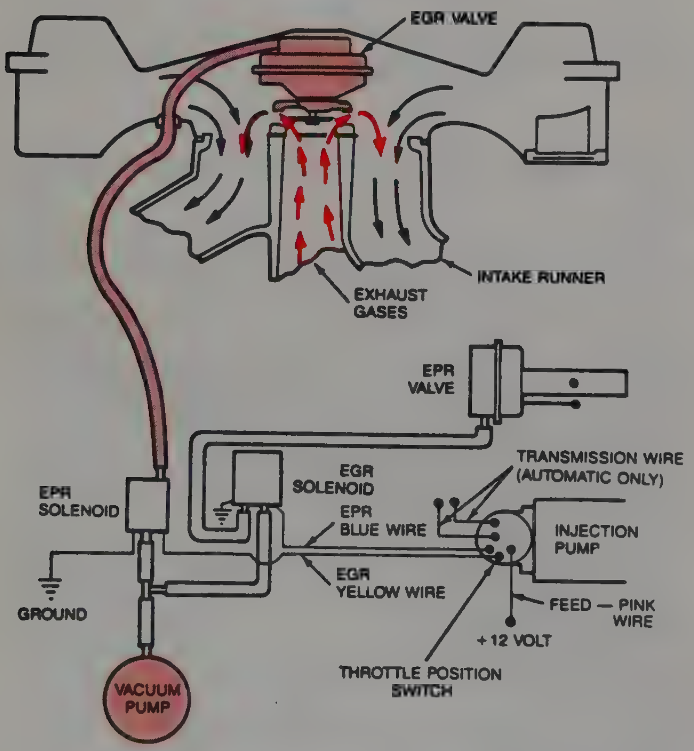

EGR VALVE
INTAKE RUNNER
EXHAUST GASES
EPR VALVE
TRANSMISSION WIRE (AUTOMATIC ONLY)
EGR SOLENOID
EPR SOLENOID
EPR BLUE WIRE
INJECTION PUMP
EGR YELLOW WIRE
FEED — PINK WIRE
+12 VOLT
GROUND
THROTTLE POSITION SWITCH
VACUUM PUMP

Fig. 35-50. Diesel engine EGR valve is actuated by vacuum created, not by engine, but by vacuum pump. (Chevrolet)

EGR COOLANT TEMPERATURE OVERRIDE SWITCH

A coolant temperature controlled vacuum switch is used on some models. The EGR vacuum hose from the carburetor port is connected to one side of the switch. The other side goes to the EGR valve. When engine temperature is below a specified point, the switch cuts off vacuum to the EGR. This improves cold engine operation. See Fig. 35-51.

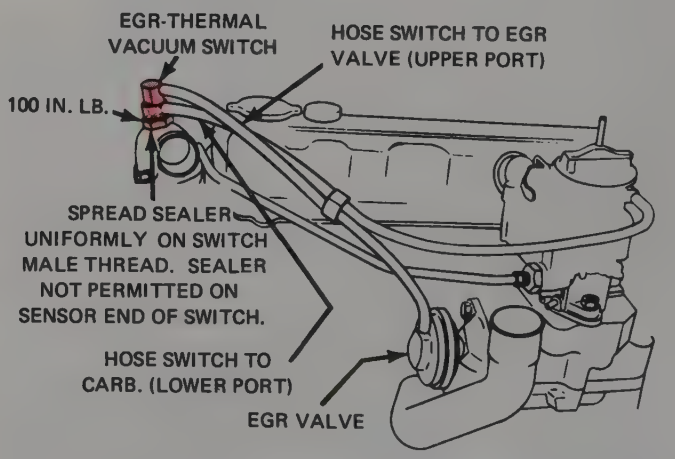

EGR-THERMAL VACUUM SWITCH
HOSE SWITCH TO EGR VALVE (UPPER PORT)
100 IN. LB.
SPREAD SEALER UNIFORMLY ON SWITCH MALE THREAD. SEALER NOT PERMITTED ON SENSOR END OF SWITCH.
HOSE SWITCH TO CARB. (LOWER PORT)
EGR VALVE

Fig. 35-51. EGR coolant temperature override switch (thermal vacuum switch) cuts off vacuum signal to EGR valve until engine warms. (Oldsmobile)

TESTING CTO SWITCH

To test the CTO switch, remove vacuum line from EGR valve or from transducer if not of the integral type. Connect vacuum gauge to line. Start cold engine. Run at 1,500 rpm. No vacuum should be indicated. Replace CTO switch if vacuum is present.

Operate engine until temperature reaches specified level.

Operate engine at 1,500 rpm. Vacuum should register on gauge. If not, replace CTO switch.

THERMOSTATIC AIR CLEANER (TAC)

The thermostatic air cleaner employs a special valve in the air inlet section. When the valve is closed, ambient temperature (cooler) air is drawn in. When the valve is fully opened, heated air (drawn from a shroud around exhaust manifold) is admitted and the cooler air excluded. At positions in between, fully open and fully closed, a blend of both heated air and cooler air is admitted, Fig. 35-52. This permits smooth engine operation on relatively lean fuel mixtures.

The air control door is actuated by either a thermostat or a vacuum motor. When the engine is started (cold), the thermostat unit is retracted and the spring-loaded air valve is held in the open (heated air) position. See A in Fig. 35-53.

As the heated air continues to flow past the thermostat unit, it slowly extends until, at the specified temperature, the air valve is fully closed. See detail B, Fig. 35-53.

Vacuum-operated thermostatic air cleaner action is depicted in Fig. 35-54. Instead of a thermostat operating the valve, a vacuum motor is employed. The cold engine start position is shown at A in Fig. 35-54. The thermal sensor bleed valve is closed and full

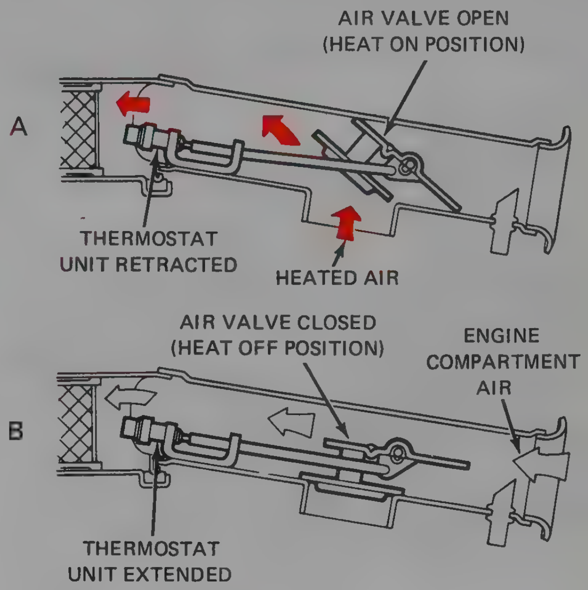

AIR VALVE OPEN
(HEAT ON POSITION)
A
THERMOSTAT
UNIT RETRACTED
HEATED AIR
AIR VALVE CLOSED
(HEAT OFF POSITION)
ENGINE
COMPARTMENT
AIR
B
THERMOSTAT
UNIT EXTENDED

Fig. 35-53. Thermostatically controlled air cleaner air valve operation. A—Cold engine. B—Normal engine temperature. (American Motors)

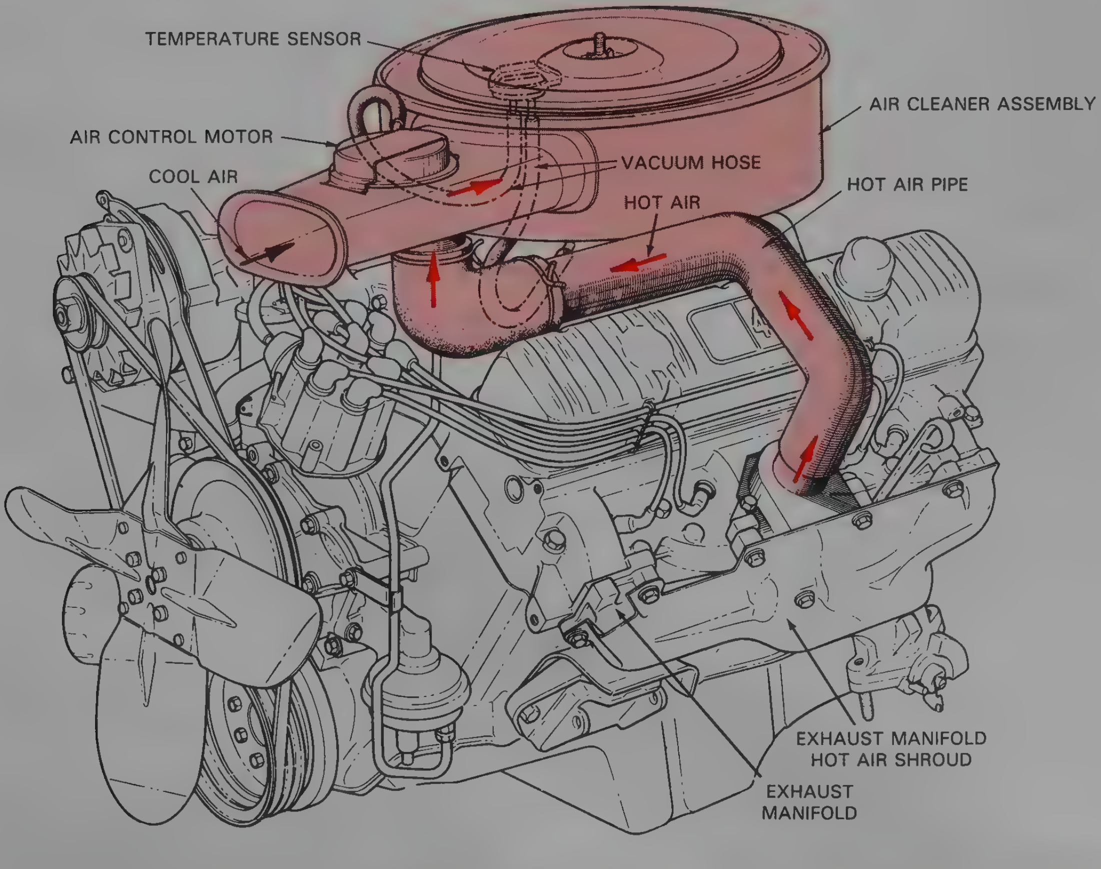

TEMPERATURE SENSOR
AIR CLEANER ASSEMBLY
AIR CONTROL MOTOR
VACUUM HOSE
COOL AIR
HOT AIR PIPE
HOT AIR
EXHAUST MANIFOLD
HOT AIR SHROUD
EXHAUST
MANIFOLD

Fig. 35-52. A thermostatically controlled air cleaner setup. (Buick)

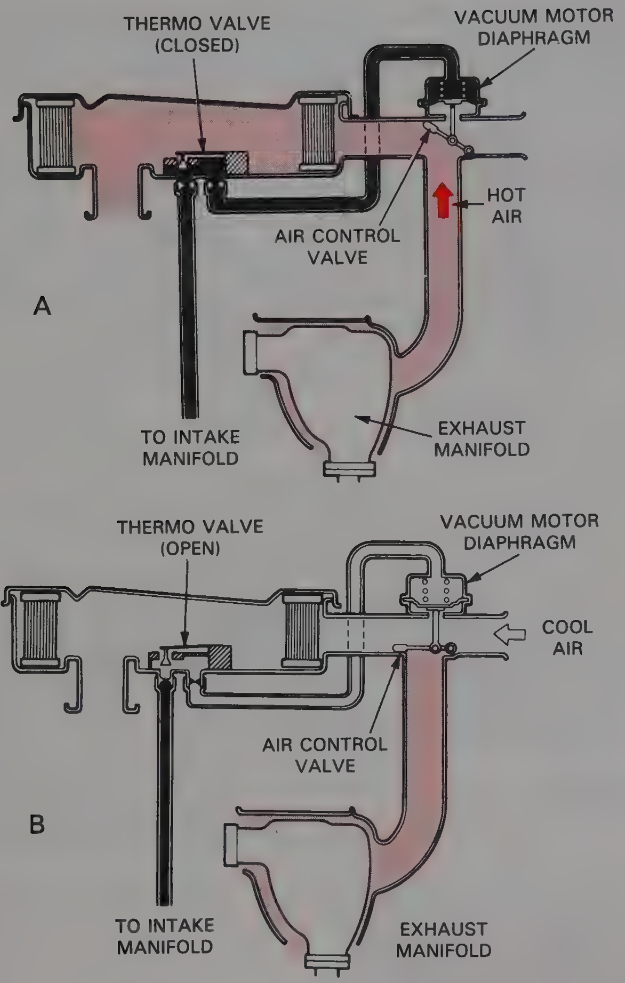

THERMO VALVE
(CLOSED)
VACUUM MOTOR
DIAPHRAGM
HOT
AIR
AIR CONTROL
VALVE
A
TO INTAKE
MANIFOLD
EXHAUST
MANIFOLD
THERMO VALVE
(OPEN)
VACUUM MOTOR
DIAPHRAGM
COOL
AIR
AIR CONTROL
VALVE
B
TO INTAKE
MANIFOLD
EXHAUST
MANIFOLD

Fig. 35-54. Vacuum motor control of thermostatically controlled air cleaner. A—Cold engine. Valve open. B—Engine at normal operating temperature. Valve closed. (Toyota)

vacuum is applied to the vacuum motor. This pulls the diaphragm up against spring pressure and fully opens the air valve to allow entrance of heated air.

When the thermal sensor warms, it opens the air bleed. This stops vacuum to the vacuum motor, thus allowing the spring to force the diaphragm down and close the valve. See B in Fig. 35-54.

A cutaway view of the entire thermostatically controlled air cleaner assembly is illustrated in Fig. 35-55. Study the parts and arrangements.

TAC SERVICE

Make certain TAC system hoses are in good condition, properly connected, and free of kinks. Remove air cleaner cover and TAPE a proper thermometer next to the sensor. Following maker's specifications, make certain that the valve "starts to open" and "full open" positions fall at the correct temperatures.

Check out vacuum bleed sensor operation as well as operation of the air motor. Fig. 35-56 illustrates the use of a hand vacuum pump to test the air motor vacuum diaphragm. Test entails checking for vacuum leakdown, starting door lift vacuum, and full open vacuum measurement.

EARLY FUEL EVAPORATION SYSTEM

The early fuel evaporation (EFE) system admits a heavy amount of exhaust heat to the exhaust crossover under the intake manifold. A special valve, vacuum operated, provides this enriched flow of hot gases during cold engine operation. This improves engine performance and reduces emissions. A thermal vacuum switch controls the EFE valve.

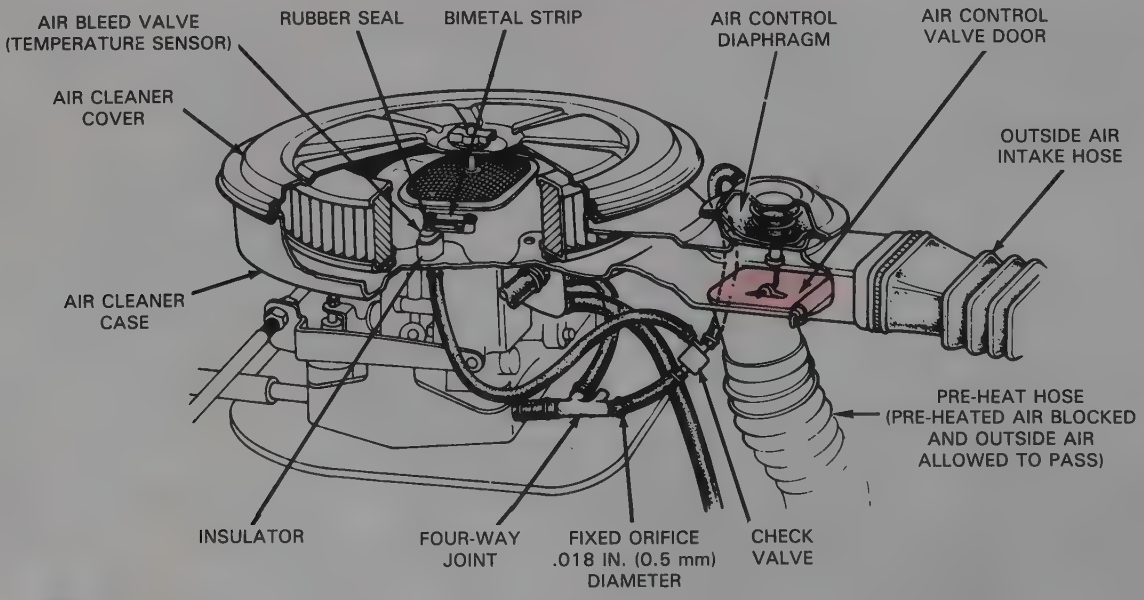

AIR BLEED VALVE
(TEMPERATURE SENSOR)
RUBBER SEAL
BIMETAL STRIP
AIR CONTROL
DIAPHRAGM
AIR CONTROL
VALVE DOOR
AIR CLEANER
COVER
OUTSIDE AIR
INTAKE HOSE
AIR CLEANER
CASE
PRE-HEAT HOSE
(PRE-HEATED AIR BLOCKED
AND OUTSIDE AIR
ALLOWED TO PASS)
INSULATOR
FOUR-WAY
JOINT
FIXED ORIFICE
.018 IN. (0.5 mm)
DIAMETER
CHECK
VALVE

Fig. 35-55. Cutaway view of a thermostatically controlled air cleaner system. (Honda)

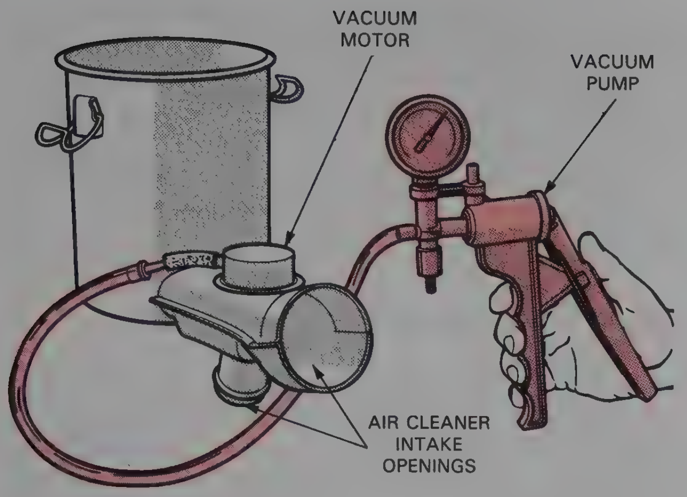

VACUUM MOTOR
VACUUM PUMP
AIR CLEANER INTAKE OPENINGS

Fig. 35-56. Testing thermostatic air cleaner vacuum motor operation. (Chrysler)

When coolant temperature reaches a certain point, the vacuum switch triggers the EFE valve which, in turn, diverts the gases through the manifold and on to the exhaust pipe. See Fig. 35-57.

Check operation of thermal vacuum switch and valve. Check hose connections and condition. For full details on the operation of the EFE system, see HEAT CONTROL VALVE in the first part of this chapter.

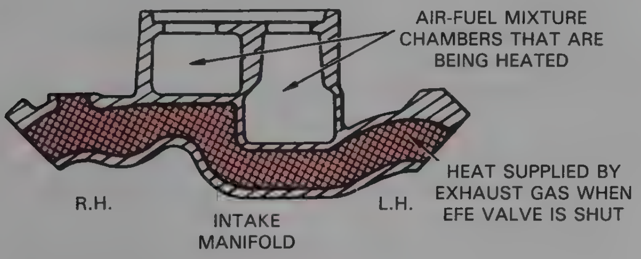

AIR-FUEL MIXTURE CHAMBERS THAT ARE BEING HEATED
R.H.
INTAKE MANIFOLD
L.H.
HEAT SUPPLIED BY EXHAUST GAS WHEN EFE VALVE IS SHUT

Fig. 35-57. Early fuel evaporation system heats intake manifold during cold engine operation. (Pontiac)

SPECIAL FUEL SYSTEM CALIBRATIONS

Some chokes are either fully electric, or electrically assisted, to speed up opening under certain engine temperature conditions. See chapter on FUEL SYSTEM SERVICE for full details on the various choke arrangements as well as other fuel system emission-related controls.

SPARK TIMING CONTROLS

A number of systems have been developed to alter ignition spark advance to meet most engine conditions. The more sophisticated systems, such as Chrysler's "Electronic Lean Burn" system, use a spark control computer along with a number of engine sensors to provide constant, almost instantaneous timing control. This permits smooth engine operation on lean fuel mixtures. For details on the lean burn system and other ignition calibrations, refer to the chapter on IGNITION SYSTEM SERVICE.

A simple "ported" vacuum spark advance control setup is shown in Fig. 35-58.

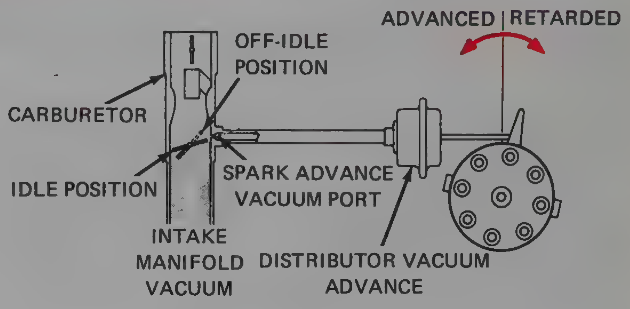

ADVANCED | RETARDED
OFF-IDLE POSITION
CARBURETOR
IDLE POSITION
SPARK ADVANCE VACUUM PORT
INTAKE MANIFOLD VACUUM
DISTRIBUTOR VACUUM ADVANCE

Fig. 35-58. A "ported" spark advance system. Spark is retarded until throttle plate moves to off-idle position. (Chevrolet)

The vacuum advance unit receives vacuum from a port that is just above the throttle plate. When the throttle is closed (idle), no vacuum is available. The spark timing remains retarded. As the throttle plate is opened, it uncovers the vacuum port and timing is advanced.

A transmission controlled spark advance system is pictured in Fig. 35-59. Below either a certain gear or

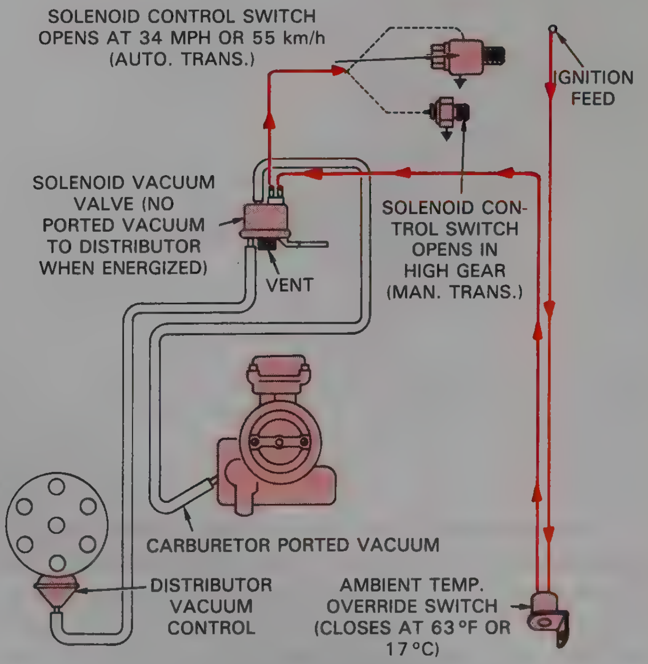

SOLENOID CONTROL SWITCH OPENS AT 34 MPH OR 55 km/h (AUTO. TRANS.)
IGNITION FEED
SOLENOID VACUUM VALVE (NO PORTED VACUUM TO DISTRIBUTOR WHEN ENERGIZED)
VENT
SOLENOID CONTROL SWITCH OPENS IN HIGH GEAR (MAN. TRANS.)
CARBURETOR PORTED VACUUM
DISTRIBUTOR VACUUM CONTROL
AMBIENT TEMP. OVERRIDE SWITCH (CLOSES AT 63 °F OR 17 °C)

Fig. 35-59. A transmission controlled spark system employing an ambient temperature override switch. (American Motors)

specific road speed (depending on transmission type), the solenoid vacuum valve is energized. It then stops vacuum from reaching the distributor vacuum control. This leaves the timing retarded, which lowers oxides of nitrogen emissions. Above the certain gear or specific road speed, the vacuum valve is de-energized, ported vacuum is applied to the distributor, and timing is advanced.

When engine (or ambient air) temperature is below a certain point, the override switch opens. This de-energizes the solenoid and provides full advance until the engine warms up. Study Fig. 35-59.

VACUUM THROTTLE MODULATING SYSTEM

Another vacuum-operated unit is used on some engines to crack open the throttle slightly during sudden deceleration periods. The vacuum throttle modulating system provides additional air, leaning out the mixture to reduce hydrocarbon emissions.

CLOSED LOOP SYSTEMS

Closed loop systems place a special oxygen sensor in the exhaust stream to constantly monitor emission levels. One type is shown in Fig. 35-60.

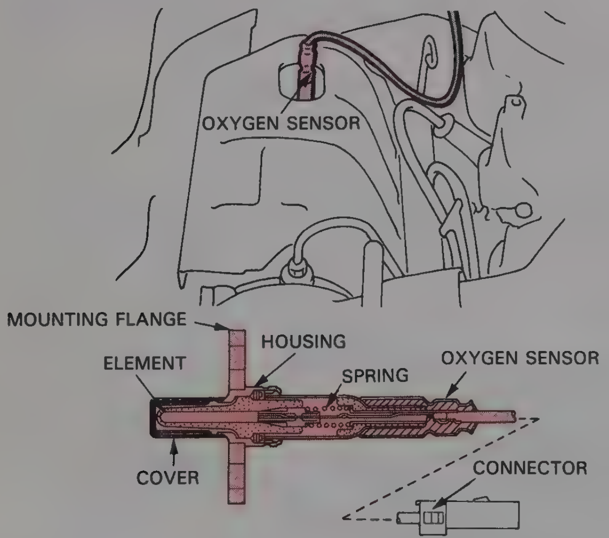


Fig. 35-60. Oxygen sensor assembly. Sensor mounts in exhaust stream and provides constant monitoring of emission levels. (Chrysler)

As the oxygen sensor responds to emission changes, it sends an electrical signal to an electronic control unit. The control unit (computer) receives constant electric "signals" from the oxygen sensor. Based on the information from the oxygen sensor and other sensors (engine temperature, car speed, engine rpm, atmospheric pressure), the computer makes constant changes in the air-fuel mixture, engine timing, EGR, and other functions. This highly efficient system, in effect, constantly monitors its own exhaust, then makes the adjustments necessary to maintain the lowest possible emission levels.

Study the closed loop system pictured in Fig. 35-61. Note the various sensors and how they relate to the overall system.

CATALYTIC CONVERTER

To further reduce exhaust emissions, a great number of cars are equipped with CATALYTIC CONVERTERS. Properly designed converters, in good condition, produce significant reductions in the levels of hydrocarbon (HC) and carbon monoxide (CO). Nitrogen oxides (NOx) are also lowered in converters containing RHODIUM as one of the catalyst agents.

Some vehicles use a single converter while others employ a small unit close to the exhaust manifold. This unit starts the reaction and heats up the exhaust. A larger downstream converter continues and completes the burning and reduction process. Air may also be injected into the exhaust between the two converters or into the converter itself. See Figs. 35-62 and 35-63.

CONVERTER CONSTRUCTION

A catalytic converter basically consists of three parts: stainless steel shell, catalyst coated core, exterior insulation and shielding.

Stainless steel is used because converter temperatures can run up to, and above, 1,600°F (861°C). This high heat level also requires the use of insulation and shielding to protect the underside of the car and the ground beneath it.

The converter core is made two ways. One technique employs a great number of porous ceramic (aluminum oxide) beads or pellets about an eighth of an inch in diameter. The pellets are thinly coated with a mixture of platinum (70 percent) and palladium (30 percent). The coated pellets are placed in a perforated container located inside the converter shell. Fig. 35-63 illustrates a typical dual bed (layer), pellet type catalytic converter.

The other method of construction uses a continuous piece of extruded ceramic substrate coated with aluminum oxide. The aluminum oxide is coated with a platinum and palladium mixture. The honeycomb substrate is separated and supported by a corrugated wire mesh. This core is then secured in the converter shell. See Fig. 35-64.

Some converters also use rhodium in addition to the regular platinum and palladium. The rhodium helps to reduce NOx (nitrogen oxide) emissions.

Some systems may employ a MINI converter upstream of a larger unit. Look at Fig. 35-65.

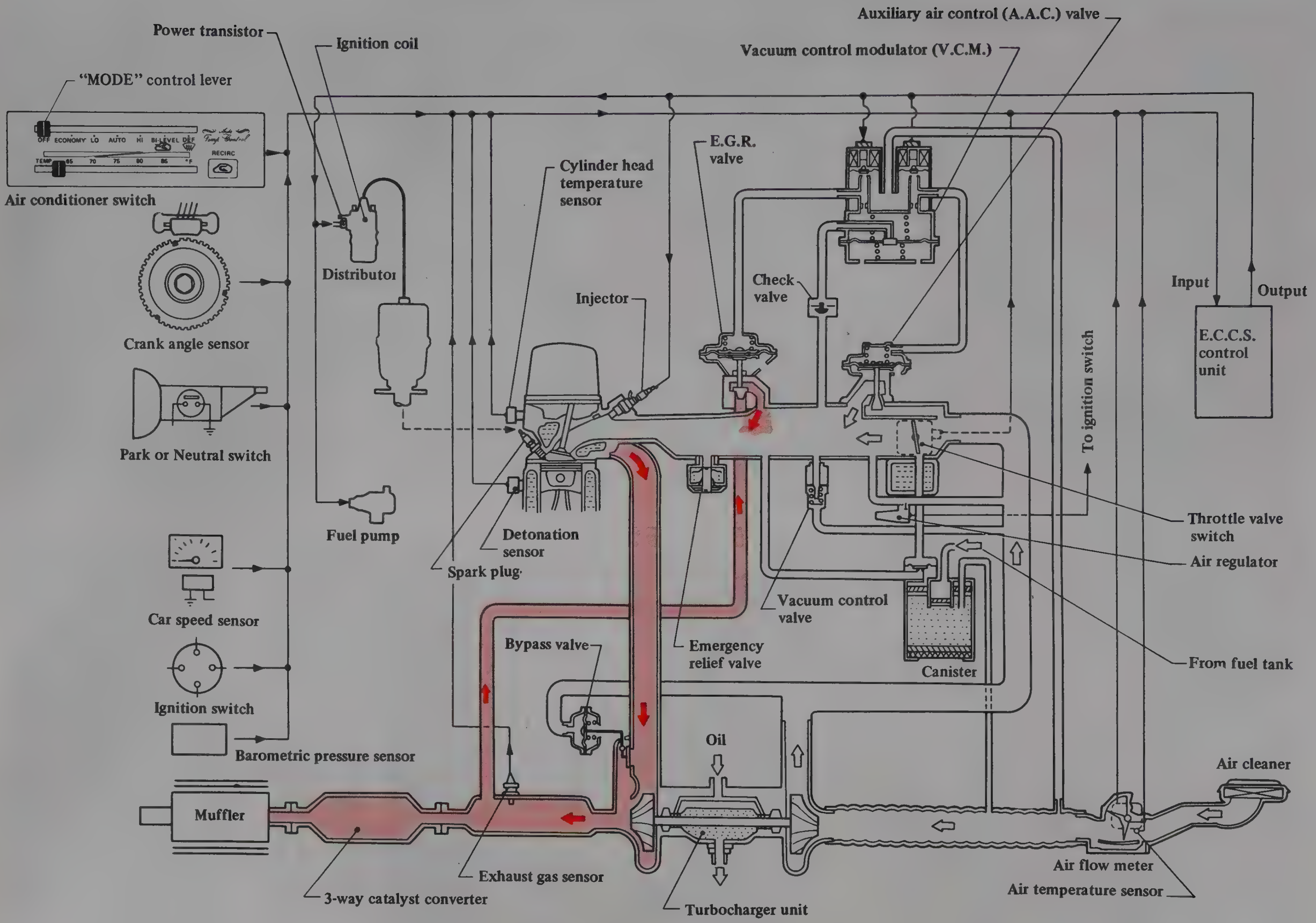

Power transistor
Ignition coil
"MODE" control lever
Air conditioner switch
Crank angle sensor
Park or Neutral switch
Car speed sensor
Ignition switch
Barometric pressure sensor
Muffler
3-way catalyst converter
Exhaust gas sensor
Distributor
Fuel pump
Cylinder head temperature sensor
Injector
Detonation sensor
Spark plug
Bypass valve
Emergency relief valve
Turbocharger unit
Oil
E.G.R. valve
Check valve
Vacuum control valve
Canister
Auxiliary air control (A.A.C.) valve
Vacuum control modulator (V.C.M.)
To ignition switch
Input
Output
E.C.C.S. control unit
Throttle valve switch
Air regulator
From fuel tank
Air cleaner
Air flow meter
Air temperature sensor
OFF ECONOMY LO AUTO HI BI-LEVEL DEF
RECIRC
TEMP 65 70 75 80 85 °F

Fig. 35-61. A "Closed Loop" emission control system. Signals from exhaust sensor and other sensors cause electronic control unit to adjust air-fuel ratio, EGR action, ignition timing, etc., to provide lowest possible emission levels. Study various circuits and systems. (Nissan)

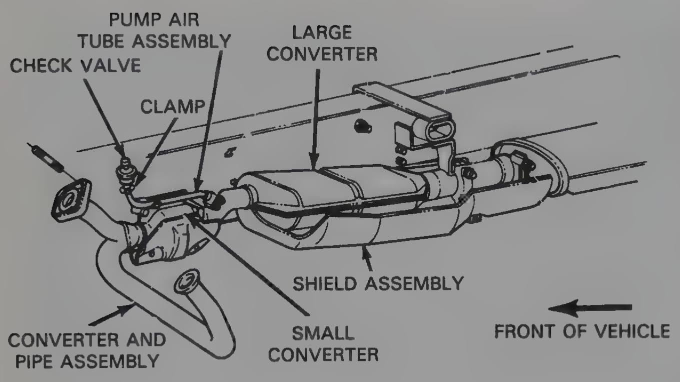

PUMP AIR TUBE ASSEMBLY
CHECK VALVE
LARGE CONVERTER
CLAMP
SHIELD ASSEMBLY
CONVERTER AND PIPE ASSEMBLY
SMALL CONVERTER
FRONT OF VEHICLE

Fig. 35-62. Dual converter setup. Note small converter close to exhaust manifold connecting pipes. Pump air is fed into exhaust pipe connecting small and large converters. (Ford)

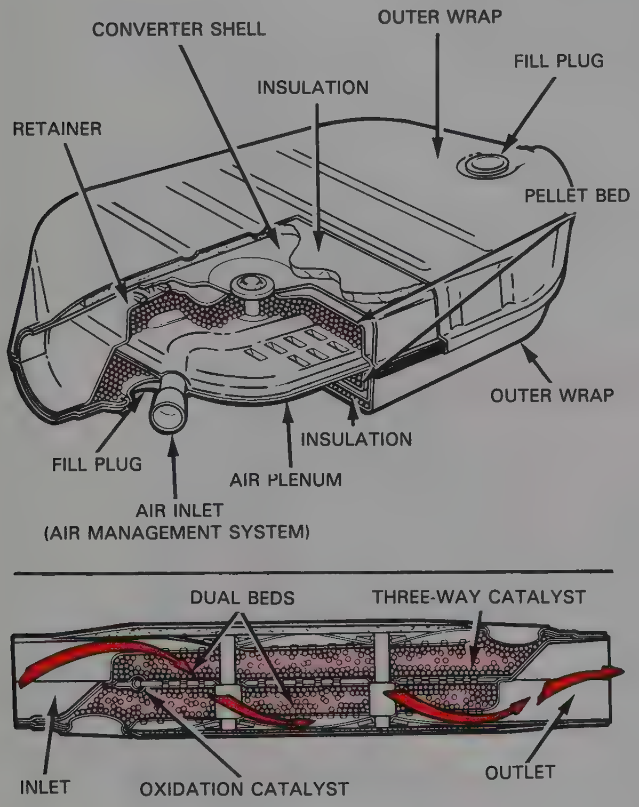

CONVERTER SHELL
OUTER WRAP
FILL PLUG
INSULATION
RETAINER
PELLET BED
OUTER WRAP
INSULATION
FILL PLUG
AIR PLENUM
AIR INLET
(AIR MANAGEMENT SYSTEM)
DUAL BEDS
THREE-WAY CATALYST
INLET
OXIDATION CATALYST
OUTLET

Fig. 35-63. Catalytic converter using a dual bed, pellet type catalyst. Study exhaust flow. (Cadillac)

HOW A CATALYTIC CONVERTER WORKS

A catalyst is a substance (platinum, palladium, or rhodium in this case) that will cause an increase in the rate of a chemical reaction (exhaust gases being burned). Yet, it will not be consumed or permanently altered by the reaction.

The converter(s) is inserted into the exhaust system between the exhaust manifold and muffler. As hot exhaust gases pass through the converter, they come into contact with the catalyst coating on the ceramic pellets or monolithic substrate, depending on construction. The catalyst causes a rapid rise in the temperature of the exhaust gas, causing the hydrocarbons, carbon monoxide, and to some extent, oxides of nitrogen to change (through an oxidizing process) into harmless water vapor, carbon dioxide, etc.

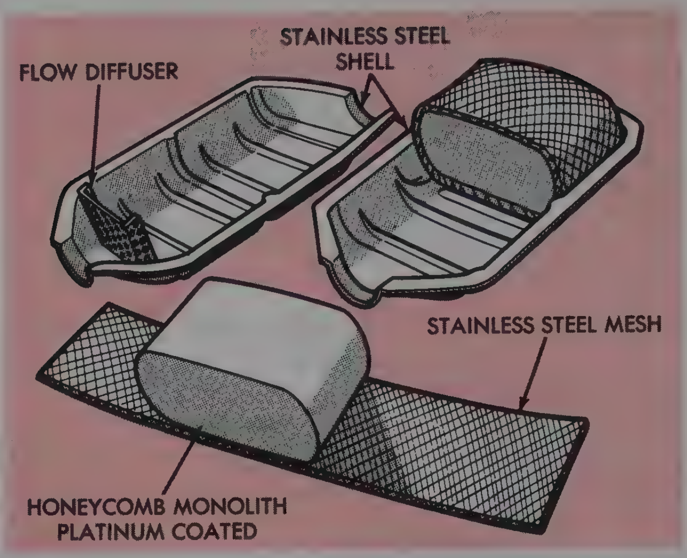

STAINLESS STEEL SHELL
FLOW DIFFUSER
STAINLESS STEEL MESH
HONEYCOMB MONOLITH PLATINUM COATED

Fig. 35-64. This catalytic converter uses a honeycomb monolith type catalyst. (Chrysler)

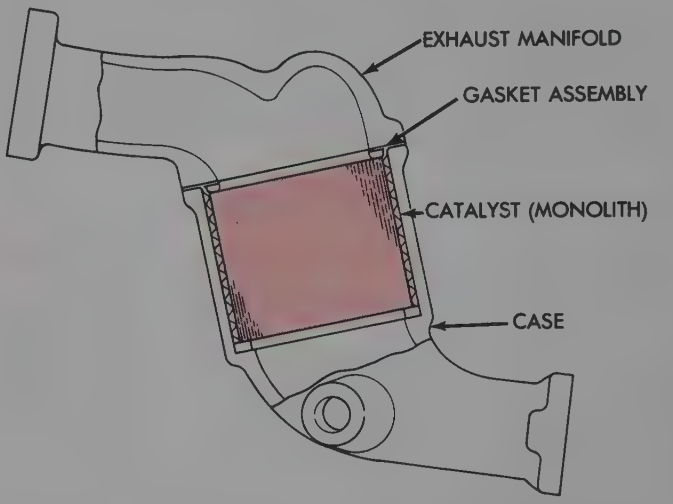

EXHAUST MANIFOLD
GASKET ASSEMBLY
CATALYST (MONOLITH)
CASE

Fig. 35-65. This "Mini" type converter is mounted near end of exhaust manifold. A larger converter will be used further downstream. (Chrysler)

Fig. 35-66 shows a converter using two separate catalyst beds. Note that air from the air injection system is being pumped into the area between the beds.

UNLEADED FUEL ONLY

If gasoline containing ANY lead is used in a car equipped with a converter, a coating will form over

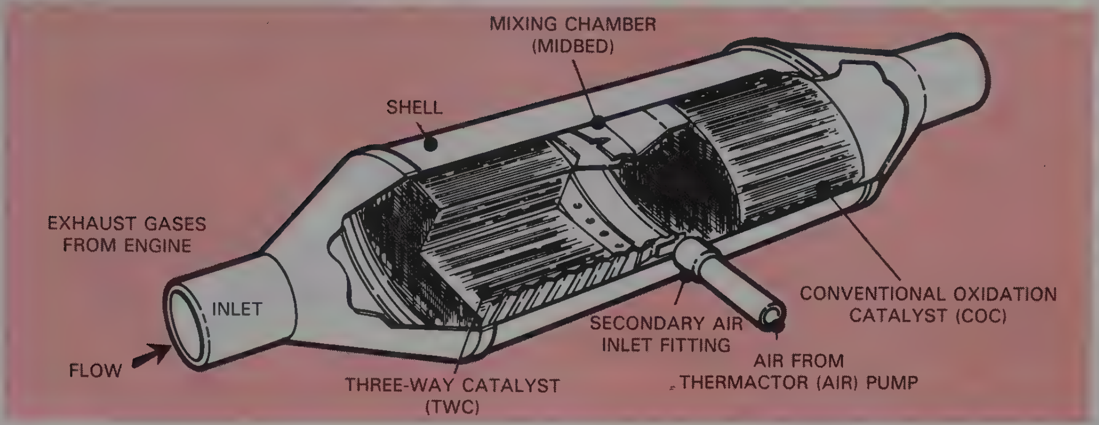

MIXING CHAMBER (MIDBED)
SHELL
EXHAUST GASES FROM ENGINE
INLET
FLOW
THREE-WAY CATALYST (TWC)
SECONDARY AIR INLET FITTING
AIR FROM THERMACTOR (AIR) PUMP
CONVENTIONAL OXIDATION CATALYST (COC)

Fig. 35-66. As exhaust gases pass through catalytic converter catalyst sections, sudden increase in temperature changes hydrocarbons and carbon monoxide into water and carbon dioxide. This converter uses two separate catalyst beds (ceramic honeycomb type) separated by a mixing chamber. Front catalyst controls hydrocarbon, carbon monoxide, and oxides of nitrogen levels. Rear catalyst controls hydrocarbons and carbon monoxide only. Air entering mixing chamber provides additional air for oxidizing (burning) process. (Ford)

the catalytic surfaces and seriously impair converter efficiency. A lead damaged converter can soon clog. This can cause excessive exhaust system back pressure, engine damage, poor performance, and a decrease in gas mileage. USE UNLEADED FUEL ONLY!

Converter equipped cars have a small filler neck that requires the use of a special unleaded fuel dispensing nozzle. This is illustrated in Fig. 35-67.

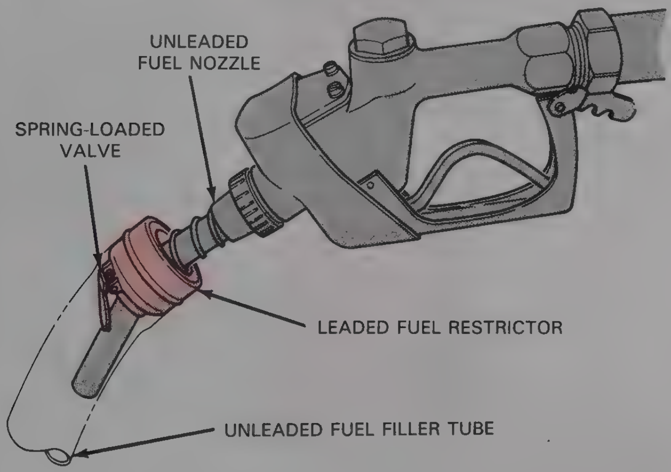


Fig. 35-67. To prevent accidental use of leaded fuel in converter equipped vehicles, fuel tank filler opening is equipped with a restrictor. All unleaded fuel pumps will have a special, small size nozzle that will pass through restrictor. (Plymouth)

OTHER CAUTIONS!

1. Catalytic converters can be damaged from the hot blast of backfiring or if fouled spark plugs or loose plug wires cause rapid converter overheating.
2. Icing can also be a problem.
3. Avoid ignition spark jump testing whenever possible.
4. Do not allow engine to idle for excessive periods — especially fast idle during warmup. The choke is still partially on and mixture is excessively rich.
5. Do not operate engine until carburetor runs out of fuel as this can cause engine backfiring.
6. Never coast with ignition key turned off as converter will fill with unburned hydrocarbons that will cause intense overheating.
7. Make engine compression tests as quickly as feasible to avoid pumping raw fuel into exhaust system.
8. When disposing of used catalyst, never throw it in with any parts coated with oil or gasoline.
9. Never use carburetor cleaner (fed through carburetor air horn especially) as converter damage can result.

KEEP IN MIND THAT ALLOWING UNBURNED FUEL TO ENTER THE CONVERTER CAN CAUSE SERIOUS OVERHEATING (RUINED CONVERTERS, MELTED FLOOR INSULATION, FIRES, AND OTHER PROBLEMS) VERY QUICKLY!

CONVERTER SERVICE LIFE

Theoretically, a catalytic converter could last the life of the car since the catalyst is not consumed. Converter service life is usually indicated as a minimum of 50,000 miles (80 000 km). This is provided the catalyst is not exposed to lead or other damage.

CONVERTER TESTING

Initial converter failure (before becoming clogged) can be difficult for the driver to detect. Engine performance would not be affected very much at first. To test converter efficiency, measure the exhaust gas temperature or use instruments to measure the amounts of HC and CO in the exhaust.

CONVERTER SERVICE — PELLET REPLACEMENT

In the event of failure, the pellet type catalytic converter permits removal of the old pellets and insertion of new ones. A special vibrator and vacuum tools are needed. Other types of catalytic converters require total replacement.

The pellet type converter has a plug in one end on the bottom. Prior to removal, install a special vacuum pump on the end of the tail pipe. Connect a shop air hose as in Fig. 35-68.

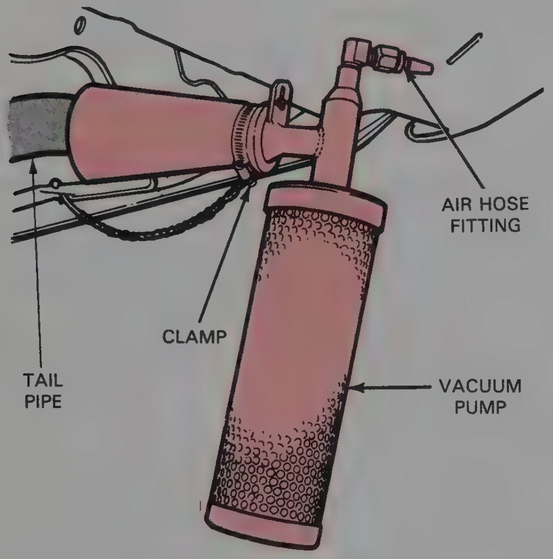


Fig. 35-68. A special vacuum pump is used on end of tail pipe as an aid in catalyst pellet replacement. (American Motors)

While vacuum pump is operating, remove pellet access plug from converter bottom. See Fig. 35-69. Attach special vibrator tool to pellet access hole and shut off vacuum pump. Apply air to vibrator tool and allow it to run for about 10 minutes or until all pellets are removed.

When removed, empty vibrator. Install refill can on vibrator. Apply shop air (80 psi or 552 kPa minimum) to both vibrator AND vacuum pump. Pellets will be drawn into the converter.

When converter is full, remove the vibrator but leave the vacuum pump running. Cap pellet access hole with special plug kit shown in Fig. 35-69. Then, remove vacuum pump. The vibrator tool is pictured in place on the converter in Fig. 35-70.

If any pellets are drawn from the tail pipe, it indicates converter failure and the whole unit must be changed.

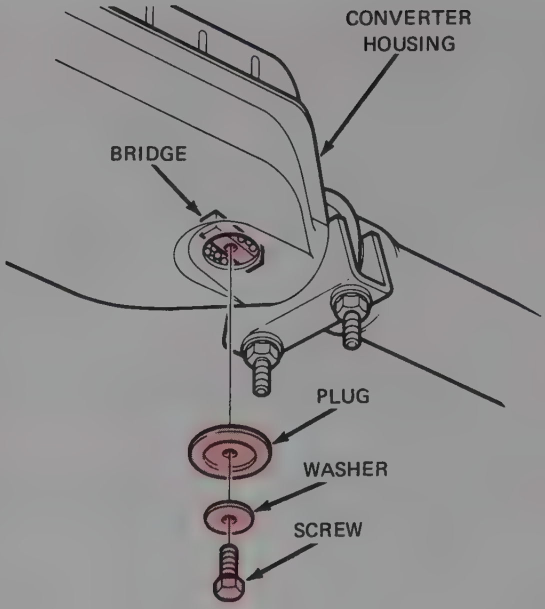


Fig. 35-69. Pellets are removed and inserted through this access hole. Shown is a special replacement plug to cap hole following pellet replacement.

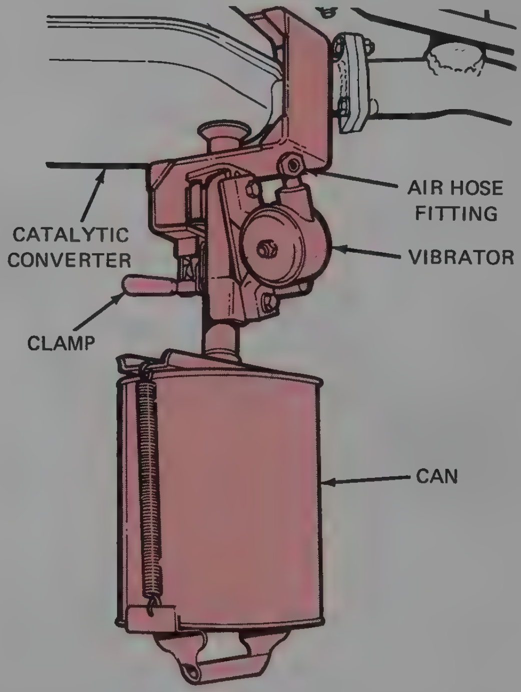


Fig. 35-70. Special vibrator tool used to remove and replace pellets in one form of catalytic converter. (American Motors)

Some converters that are damaged on the bottom area, may have that area cut away and replaced. A special kit is offered by some makers for this purpose. See Fig. 35-71.

Always be certain that all heat shielding is in good condition and properly placed. Never spray under-

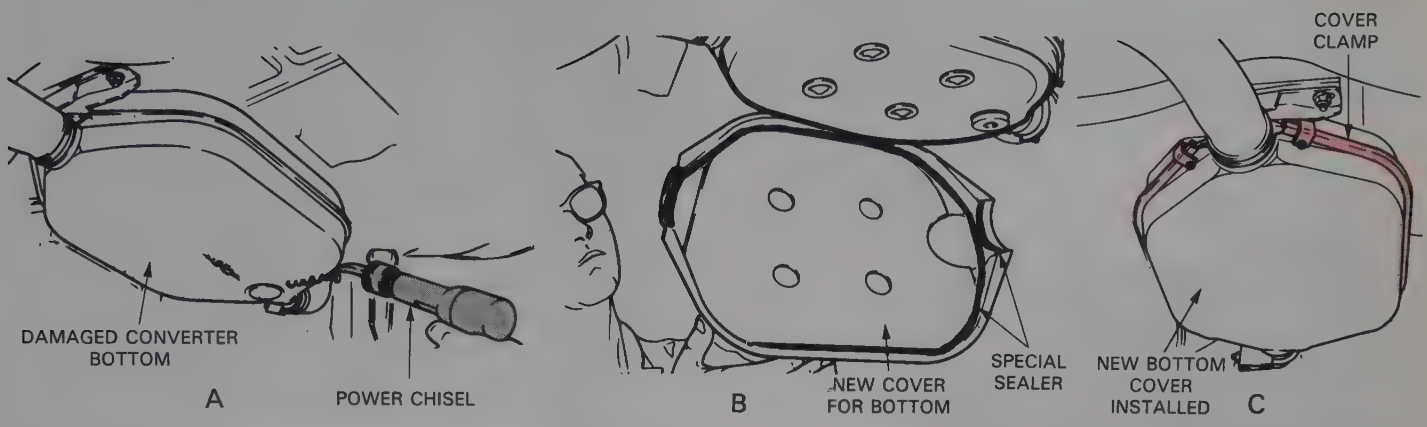

DAMAGED CONVERTER BOTTOM
A
POWER CHISEL
B
NEW COVER FOR BOTTOM
SPECIAL SEALER
COVER CLAMP
NEW BOTTOM COVER INSTALLED
C

Fig. 35-71. Replacing a damaged converter bottom shell. A—Removing old bottom using a power chisel. B—Applying sealer to new, replacement bottom. C—Attaching new bottom with special cover clamps. (Pontiac)

coating on any part of the exhaust system or any portion of the heat shielding.

EVAPORATION CONTROL SYSTEM

While there are some design variations, most evaporation control systems (ECS) employ a nonvented (to atmosphere) fuel tank. A pressure-vacuum filler cap, a liquid-vapor separator, a vent line, charcoal canister, and an excess fuel and vapor return line to the tank are featured. A roll-over valve also can be used.

The system shown in Fig. 35-72 is typical. Fuel vapors from the tank and carburetor float bowl are passed into the charcoal canister. Then, they are drawn from the canister through the purge line into the intake system and burned. Note the use of the roll-over valve in the evaporation control system diagram shown in Fig. 35-72. This valve prevents fuel leakage in the event the car is rolled over.

Air flow through typical two and three tube canisters is shown in Fig. 35-73. Study the air flow. Note the filter in the bottom of each unit. This filter requires periodic cleaning as recommended by the maker.

Some canisters have a closed bottom and admit purge air through a tube from the interior of the air cleaner. See B, Fig. 35-73.

Service the evaporation control system as indicated by the manufacturer, paying attention to time and mileage recommendations.

SERVICING THE POSITIVE CRANKCASE VENTILATION SYSTEM

Proper PCV valve functioning is IMPORTANT. Normal valve position during four modes is shown in Fig. 35-74.

To check system operation, use a suitable gauge. Use as recommended by manufacturer.

To service a PCV system, remove the connecting

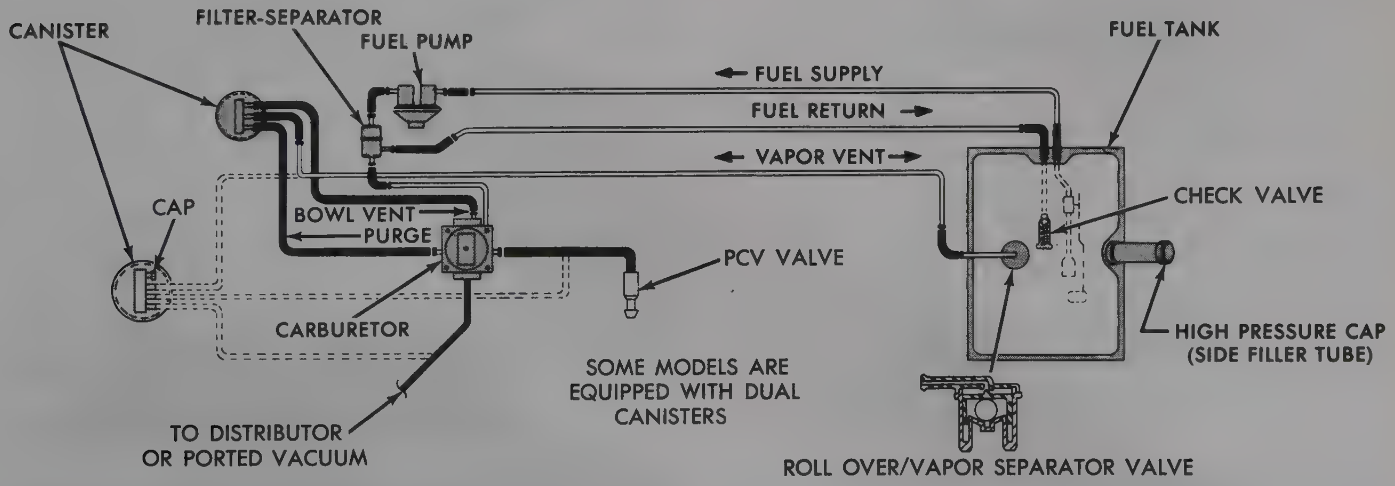

CANISTER
FILTER-SEPARATOR
FUEL PUMP
FUEL TANK
FUEL SUPPLY
FUEL RETURN
VAPOR VENT
CHECK VALVE
CAP
BOWL VENT
PURGE
PCV VALVE
CARBURETOR
HIGH PRESSURE CAP (SIDE FILLER TUBE)
SOME MODELS ARE EQUIPPED WITH DUAL CANISTERS
TO DISTRIBUTOR OR PORTED VACUUM
ROLL OVER/VAPOR SEPARATOR VALVE

Fig. 35-72. One type of evaporation control system. Study layout. (Chrysler)

hose or pipe and the control valve, Fig. 35-75.

If the valve is of the demountable, threaded type (usually has two hexagonal wrench flats) carefully take it apart. Sealed valves (usually have ONE or NO hexagonal flats) can often be cleaned by soaking in carburetor cleaner, rinsing, and blowing dry. Some valves must be replaced. Follow manufacturer's recommendations.

Reassemble the valve. A clean valve will rattle when shaken vigorously.

Rinse out the connecting hose. If system is of the older OPEN-type, rinse and reoil the breather cap. Some caps utilize a dry-type filter element. The dry-type should NOT be washed or oiled. Replace at recommended intervals or when clogged.

On a CLOSED system, clean the hose from breather, or other opening, to the air cleaner. If a special mesh

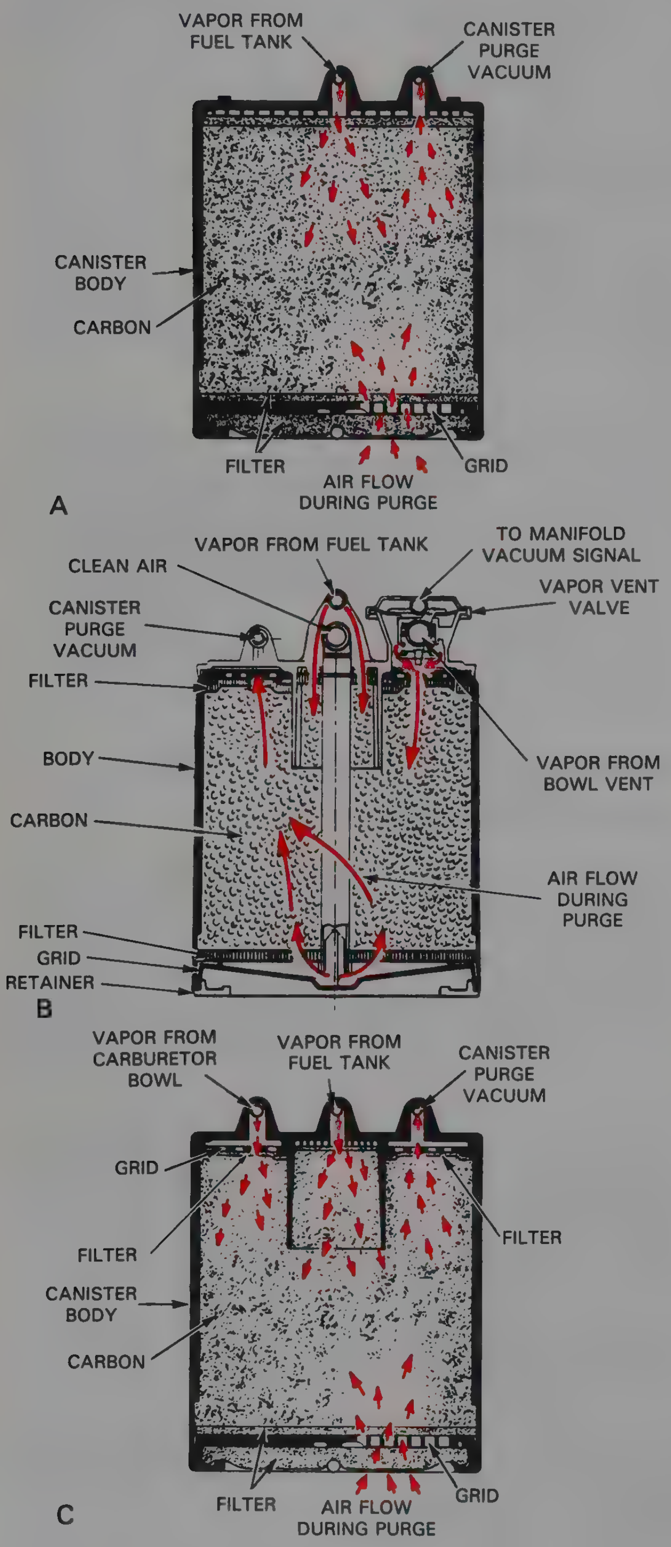

VAPOR FROM FUEL TANK
CANISTER PURGE VACUUM
CANISTER BODY
CARBON
FILTER
AIR FLOW DURING PURGE
GRID
A
VAPOR FROM FUEL TANK
TO MANIFOLD VACUUM SIGNAL
CLEAN AIR
CANISTER PURGE VACUUM
VAPOR VENT VALVE
FILTER
BODY
VAPOR FROM BOWL VENT
CARBON
AIR FLOW DURING PURGE
FILTER
GRID
RETAINER
B
VAPOR FROM CARBURETOR BOWL
VAPOR FROM FUEL TANK
CANISTER PURGE VACUUM
GRID
FILTER
FILTER
CANISTER BODY
CARBON
FILTER
AIR FLOW DURING PURGE
GRID
C

Fig. 35-73. Three types of emission system vapor canisters. A—Two tube, open bottom. B—Three tube, closed bottom. C—Three tube, open bottom. (Pontiac)

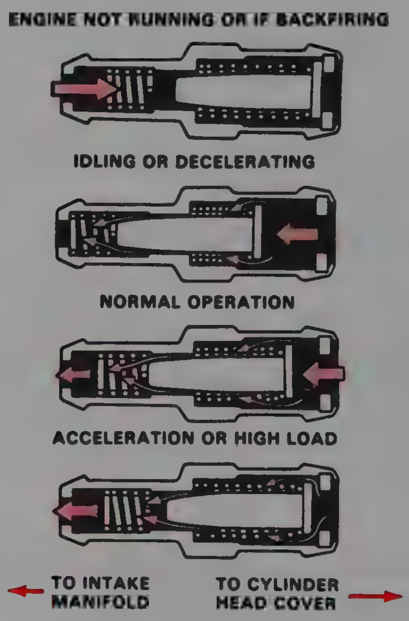

ENGINE NOT RUNNING OR IF BACKFIRING
IDLING OR DECELERATING
NORMAL OPERATION
ACCELERATION OR HIGH LOAD
TO INTAKE MANIFOLD
TO CYLINDER HEAD COVER

Fig. 35-74. Operation of PCV valve when engine is off or backfiring, idling or decelerating, operating normally, and accelerating.

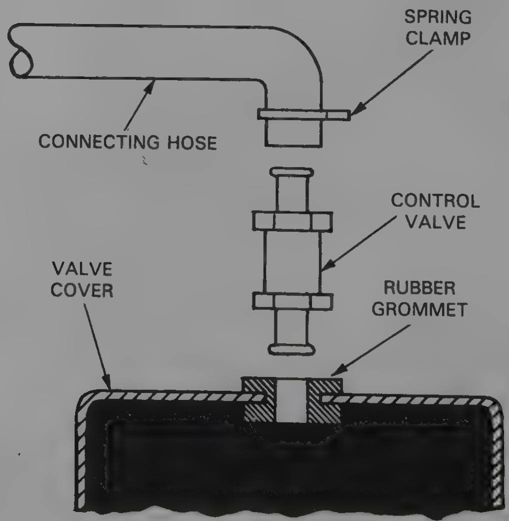

SPRING CLAMP
CONNECTING HOSE
CONTROL VALVE
VALVE COVER
RUBBER GROMMET

Fig. 35-75. Remove hose and control valve to service PCV system.

is used in the air cleaner for filtering the incoming air to the crankcase, wash and reoil or replace as recommended.

Install valve SO IT FACES THE CORRECT DIRECTION. Check for directional marks on valve. Connect all hose (make certain hose is open). Start engine and bring to operating temperature before checking operation.

DO NOT INSTALL A CLOSED-TYPE BREATHER CAP ON AN OPEN PCV SYSTEM. Rusting of engine parts and heavy sludging will soon follow.

DO NOT INTERCHANGE PCV VALVES. Always use a valve designed for the car being serviced.

FOR NORMAL USAGE, CHANGING OR CLEANING THE VALVE ONCE PER YEAR OR EACH 12,000 MILES, WHICHEVER COMES FIRST, IS USUALLY SATISFACTORY. More frequent cleaning may be required if engine is badly worn or if it is operating under adverse conditions.

CHECK PCV OPERATION AND CLEAN AND REOIL BREATHER CAP (OPEN-TYPE) AT EVERY OIL CHANGE.

Remember, the PCV system MUST be kept CLEAN. Rough idle, poor mileage, and rapid engine wear will result when the system is inoperative. A modern CLOSED PCV system is illustrated in Fig. 35-76.

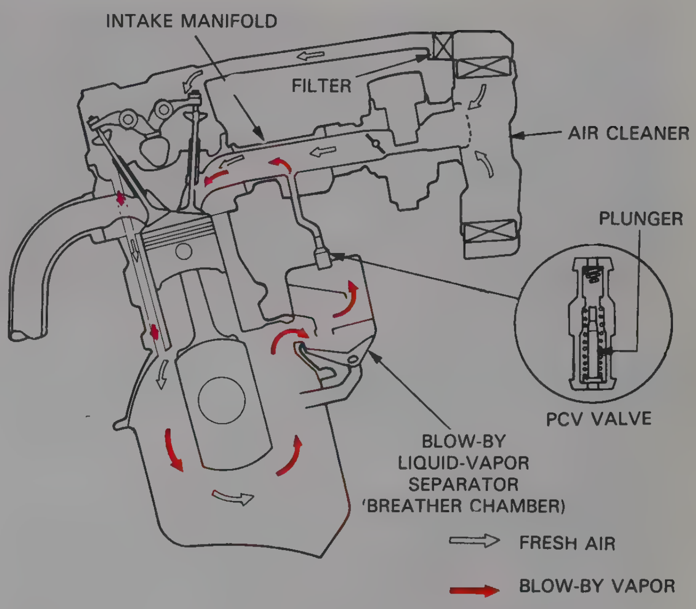


Fig. 35-76. Typical, modern CLOSED PCV system. Note how PCV valve allows vacuum from intake manifold to draw fresh air through the air filter and into the engine crankcase. This effectively removes harmful blow-by gases from crankcase where they enter intake air for burning in combustion chamber. Note use of liquid-vapor separator to prevent engine oil from being drawn into intake manifold. (Honda)

TUNE-UP IS IMPORTANT

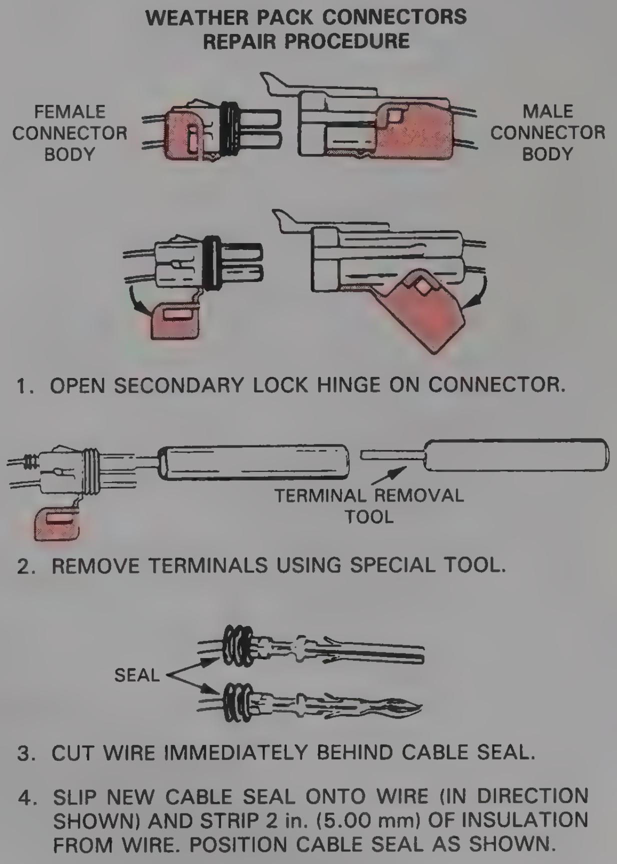
A PROPERLY OPERATING EMISSION CONTROL SYSTEM CANNOT SUCCESSFULLY REDUCE HYDROCARBON, CARBON MONOXIDE, AND OXIDES OF NITROGEN UNLESS THE ENGINE IS PROPERLY TUNED AND IS IN SOUND MECHANICAL CONDITION. KEEP THIS IN MIND!

EMISSION CONTROL WIRING

Some electrical units in the emission control system operate at very low levels of current and/or voltage. For example, the oxygen sensor can operate on voltage as low as 500 μV (microvolt — one millionth volt) and 250 μA (microampere — one millionth ampere).

As a result, all connections must be CLEAN, TIGHT, and, when needed, SEALED from the atmosphere.

When removing, replacing, or repairing wiring harness connectors, use care to avoid bending. When repairing, use recommended procedures and materials to insure a proper connection. Solder all splices. Fig. 35-77 shows recommended repair procedure for one specific connector.

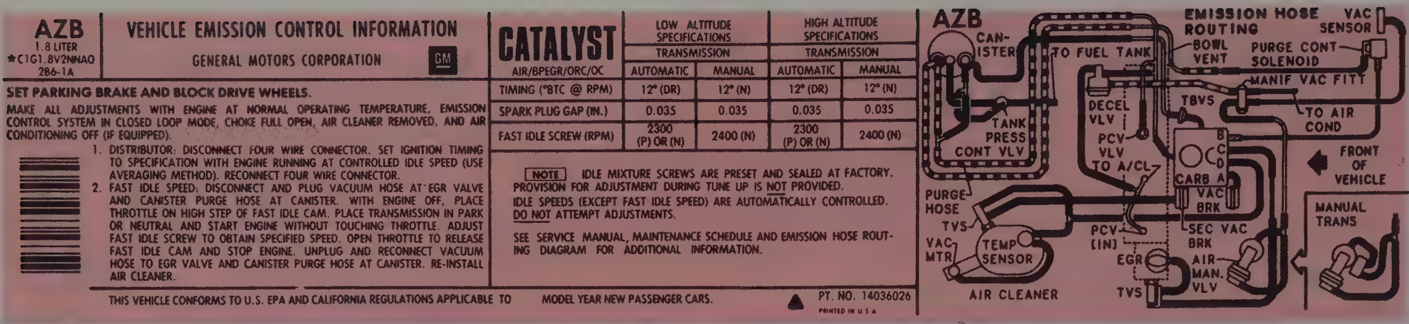


1. OPEN SECONDARY LOCK HINGE ON CONNECTOR.
2. REMOVE TERMINALS USING SPECIAL TOOL.
3. CUT WIRE IMMEDIATELY BEHIND CABLE SEAL.
4. SLIP NEW CABLE SEAL ONTO WIRE (IN DIRECTION SHOWN) AND STRIP 2 in. (5.00 mm) OF INSULATION FROM WIRE. POSITION CABLE SEAL AS SHOWN.

Fig. 35-77. Repair procedure for one type of special wire connector designed to hold terminals in tight contact and to shield them from underhood environment. (Oldsmobile)

EMISSION LABEL

All vehicles, for some time, have been equipped with an underhood emission information label. This label



AZB
1.8 LITER
*C1G1.8V2NNAQ
286-1A

VEHICLE EMISSION CONTROL INFORMATION

GENERAL MOTORS CORPORATION GM

SET PARKING BRAKE AND BLOCK DRIVE WHEELS.

MAKE ALL ADJUSTMENTS WITH ENGINE AT NORMAL OPERATING TEMPERATURE, EMISSION CONTROL SYSTEM IN CLOSED LOOP MODE, CHOKE FULL OPEN, AIR CLEANER REMOVED, AND AIR CONDITIONING OFF (IF EQUIPPED).

1. DISTRIBUTOR: DISCONNECT FOUR WIRE CONNECTOR. SET IGNITION TIMING TO SPECIFICATION WITH ENGINE RUNNING AT CONTROLLED IDLE SPEED (USE AVERAGING METHOD). RECONNECT FOUR WIRE CONNECTOR.
2. FAST IDLE SPEED: DISCONNECT AND PLUG VACUUM HOSE AT EGR VALVE AND CANISTER PURGE HOSE AT CANISTER. WITH ENGINE OFF, PLACE THROTTLE ON HIGH STEP OF FAST IDLE CAM. PLACE TRANSMISSION IN PARK OR NEUTRAL AND START ENGINE WITHOUT TOUCHING THROTTLE. ADJUST FAST IDLE SCREW TO OBTAIN SPECIFIED SPEED. OPEN THROTTLE TO RELEASE FAST IDLE CAM AND STOP ENGINE. UNPLUG AND RECONNECT VACUUM HOSE TO EGR VALVE AND CANISTER PURGE HOSE AT CANISTER. RE-INSTALL AIR CLEANER.

CATALYST AIR/BPEGR/ORC/OC	LOW ALTITUDE SPECIFICATIONS		HIGH ALTITUDE SPECIFICATIONS	
	TRANSMISSION		TRANSMISSION	
	AUTOMATIC	MANUAL	AUTOMATIC	MANUAL
TIMING (°BTC @ RPM)	12° (DR)	12° (N)	12° (DR)	12° (N)
SPARK PLUG GAP (IN.)	0.035	0.035	0.035	0.035
FAST IDLE SCREW (RPM)	2300 (P) OR (N)	2400 (N)	2300 (P) OR (N)	2400 (N)

NOTE IDLE MIXTURE SCREWS ARE PRESET AND SEALED AT FACTORY. PROVISION FOR ADJUSTMENT DURING TUNE UP IS NOT PROVIDED.

IDLE SPEEDS (EXCEPT FAST IDLE SPEED) ARE AUTOMATICALLY CONTROLLED. DO NOT ATTEMPT ADJUSTMENTS.

SEE SERVICE MANUAL, MAINTENANCE SCHEDULE AND EMISSION HOSE ROUTING DIAGRAM FOR ADDITIONAL INFORMATION.

THIS VEHICLE CONFORMS TO U.S. EPA AND CALIFORNIA REGULATIONS APPLICABLE TO MODEL YEAR NEW PASSENGER CARS.

PT. NO. 14036026
PRINTED IN U S A

Fig. 35-78. A typical, underhood emission control label. Remember to USE information on these labels as they give very specific information for car they are placed on. Do not use this information for any other car, even one of same year and model. Labels will vary depending upon vehicle destination, engine size and type, transmission, fuel system, etc. (Chevrolet)

provides the mechanic with important tune-up specifications for that EXACT vehicle. ALWAYS USE and FOLLOW the information provided to be certain the vehicle complies with emission standards. A typical emission label is pictured in Fig. 35-78. Remember that the label is ONLY for one specific vehicle. Never remove the label.

OVERALL EMISSION SYSTEM

Remember! When diagnosing engine or emission problems, keep in mind that many of the systems are interrelated. A properly running engine requires a careful balancing of all systems. A failure or maladjustment in one system can affect the operation of other systems.

Use care in diagnosing. THINK! REASON! Do not "PLUNGE" in, but work CAREFULLY. Follow manufacturer's specs. If diagnostic connectors are employed on the vehicle, use them. Use proper test equipment.

Always test vehicle emission levels for compliance with established standards. In addition to those already discussed, remember the following cautions:

1. Do not use an impact wrench to remove or install thermo sensors or thermo switches.
2. Never drop vital electrical units such as thermal relays, sensors, etc., on a hard surface. If they ARE dropped, REPLACE them.
3. When separating electrical connectors, apply pressure to the connector body and NOT to the wires.
4. Do not pierce insulation.
5. Do not bend connector terminals through careless use of test probes.
6. To remove a vacuum line, pull on the end. Never pull in the center of the hose.
7. Do not force vacuum hoses over connectors that are too large. This can cause splitting. When using a vacuum gauge, make certain connector does not fit too tightly as hose will be stretched. When returned to its own connection, it will leak.
8. Never steam clean an engine without first protecting carburetor, distributor, air pump, EGR vacuum modulator, air filter, etc. Never apply steam directly to any electrical units.
9. When possible, always disconnect battery before testing or making electrical repairs.

Fig. 35-76 shows the various emission control devices as employed by one maker.

REMEMBER: Proper diagnosis is impossible unless the engine is in sound mechanical condition and is properly tuned. Always check these areas FIRST.

SUMMARY

The exhaust gases, upon leaving the cylinder head, enter the exhaust manifold.

Use penetrating oil to help remove exhaust manifold and exhaust manifold-to-exhaust pipe fasteners.

When installing an exhaust manifold, clean mounting surfaces. Use a gasket where needed and torque to specifications. Retorque following engine operation if required.

The exhaust manifold heat control valve causes a portion of the exhaust gases to warm the fuel charge during engine warm-up.

The EXHAUST PIPE carries the exhaust gases from the exhaust manifold to the converter and/or muffler. Exhaust systems are of the single or dual type.

Mufflers are generally of the baffled, reverse flow, straight-through, or chambered pipe design.

Mufflers are often ceramic or aluminum coated to increase service life. Some are made of stainless steel. Occasionally, the entire system may be stainless.

Proper tools speed up exhaust system work and make for a better job. Some of the handy tools are: power chisel, hand pipe cutter, joint heater, pipe expander, straightening cone, chain wrench, and power wrench.

Remember:

1. Pipe clamps must be of the correct size and design.
2. A frame contact hoist is handy for exhaust system work.
3. Use penetrating oil on clamp and bracket fasteners.
4. Clean all joints thoroughly.
5. Use exhaust system sealer on pipe-muffler joints.
6. Pipe depth in nipple must be correct.

7. Position clamps properly.
8. Cut exhaust pipe when an integral part of the muffler.
9. Align exhaust system for proper clearance.
10. Check for leaks when job is complete.
11. Use mufflers and pipes of the correct size and design for the specific car.

To reduce emission of hydrocarbons and carbon monoxide, cars are being equipped with PCV (Positive Crankcase Ventilation) and air injection systems. The PCV systems draws the crankcase fumes into the cylinders for burning.

The air injection system forces fresh air into the exhaust gases in the valve ports near the exhaust valves. This air causes the gases to continue burning, thus reducing the hydrocarbon level and changing much of the carbon monoxide into carbon dioxide.

In addition to the forced air, generally modifications are made to the distributor and carburetor. Intake air may be heated by use of a thermostatic air cleaner.

The air injection system uses an air pump. The air is filtered with a special filter or is drawn in through the carburetor air cleaner.

The air is directed into the valve ports by a distribution manifold and injection tubes.

A check valve prevents exhaust gases from traveling into the air injection system.

A diverter (anti-backfire) valve is used to prevent backfiring upon sudden closing of the carburetor throttle valve. Hoses connect all parts of the system.

The injection system air cleaner (where used) must be changed at specified intervals. Maintain pump belt tension as specified. Hoses, check valve, anti-backfire valve, air distribution manifold, and injection tubes do not require periodic attention.

When cleaning system, never use air pressure on the check valve or anti-backfire valve. Before testing system, check hoses for kinks or leaks. Bring engine to normal operating temperature.

The EGR system reduces NOx by lowering combustion chamber flame temperature. The BPV (back pressure transducer valve), where used, controls the strength of the vacuum applied to the EGR valve.

Spark timing controls are used.

Closed loop systems monitor the exhaust and alter timing, fuel mixtures, etc., to lower emissions.

Catalytic converters are used in the exhaust system to further lower emissions. Use unleaded fuel only.

The evaporative control system prevents gasoline vapors (hydrocarbons) from being discharged into the atmosphere from the fuel tank or carburetor.

In order for the emission control system to function as designed, the engine must be in proper tune and in sound mechanical condition.

PROBLEM DIAGNOSIS: EXHAUST SYSTEM

PROBLEM: EXHAUST ODOR ENTERS CAR DURING HIGHWAY OPERATION

Possible Cause	Correction
1. Leaking exhaust system connections.	1. Tighten connections. Repair or, if needed, replace units.
2. Holes in muffler or pipe system.	2. Replace defective units.
3. Tail pipe does not protrude far enough to rear or side.	3. Install correct length of pipe or an extension.
4. Oil drips on hot exhaust system.	4. Repair oil leaks.
5. Hole(s) in body or fire wall.	5. Locate and seal holes.
6. Operating vehicle with back window down.	6. Inform owner.

PROBLEM: ENGINE LACKS POWER

Possible Cause	Correction
1. Clogged muffler.	1. Replace muffler.
2. Clogged or kinked exhaust or tail pipe.	2. Replace pipe.
3. Muffler or pipes too small for car.	3. Install muffler and pipes of the correct size and type.
4. Catalytic converter clogged or crushed shut.	4. Replace with new converter.

PROBLEM: EXCESSIVE EXHAUST SYSTEM NOISE

Possible Cause	Correction
1. Holes in muffler or pipes.	1. Replace defective units.
2. System connections leaking.	2. Repair connections.
3. Exhaust manifold gaskets blown.	3. Replace gaskets.
4. Muffler of incorrect design.	4. Replace with correct muffler.
5. Muffler burned inside.	5. Replace muffler.
6. Straight-through design muffler carboned up.	6. Replace muffler.
7. Hole in catalytic converter.	7. Repair or replace converter.

PROBLEM: EXHAUST SYSTEM MECHANICAL NOISE

Possible Cause	Correction
1. System improperly aligned.	1. Align system.
2. Support brackets loose, bent, or broken.	2. Tighten.
3. Incorrect muffler or pipes.	3. Install correct muffler or pipes.
4. Baffle loose in muffler.	4. Replace muffler.
5. Manifold heat control valve rattles.	5. Replace thermostatic spring.
6. Engine mounts worn.	6. Replace engine mounts.
7. Damaged or defective catalytic converter.	7. Repair or replace converter.

PROBLEM DIAGNOSIS: EXHAUST EMISSION CONTROL SYSTEM

PROBLEM: AIR PUMP NOISY

Possible Cause	Correction
1. Loose belt.	1. Adjust belt tension.
2. Bearing defective.	2. Replace bearing.
3. Vane bearings defective.	3. Replace vane assembly.
4. Carbon seals or shoes defective.	4. Replace seals or shoes.
5. Air leak in hose.	5. Replace hose.
6. Loose hose connection.	6. Tighten connection.
7. Defective (leaking) relief valve.	7. Replace relief valve.
8. Air cleaner air leak.	8. Tighten cleaner.
9. Pump bracket loose.	9. Tighten bracket fasteners.
10. Vanes striking housing bore when pump is new.	10. Normal. With some driving, "chirping" sound should soon stop.
11. Hoses touching other parts of the car.	11. Align and secure hoses.
12. Vacuum differential valve defective.	12. Replace valve.
13. Bypass valve defective.	13. Replace valve.
14. Pump failure.	14. Replace pump.
15. Filter plugged.	15. Clean or replace.
16. Seized pump.	16. Replace pump.
17. Loose pulley.	17. Tighten to specs. Replace pulley if damaged.

PROBLEM: AIR INJECTION SYSTEM INOPERATIVE

Possible Cause	Correction
1. Drive belt loose or broken.	1. Adjust tension or replace.
2. Pump seized or frozen.	2. Repair or replace pump.
3. Pump relief valve stuck open.	3. Replace relief valve.
4. Hose connection loose.	4. Tighten connection.
5. Hose disconnected or broken.	5. Attach and tighten or replace.
6. Hose kinked.	6. Replace hose. Align and secure.
7. Check valve stuck shut.	7. Replace check valve.
8. Air distribution manifold or injection tubes clogged.	8. Clean or replace.
9. Air cleaner clogged.	9. Replace air cleaner.
10. Diverter valve inoperative.	10. Replace diverter valve.

PROBLEM: SYSTEM HOSE BURNED OR BAKED

Possible Cause	Correction
1. Check valve stuck open.	1. Replace check valve.

PROBLEM: EXHAUST SYSTEM BURNED

Possible Cause	Correction
1. Relief valve in air injection pump stuck shut.	1. Replace relief valve.

PROBLEM: ENGINE BACKFIRES IN THE EXHAUST SYSTEM

Possible Cause	Correction
1. Diverter valve vacuum line leaking, kinked, or disconnected.	1. Replace line.
2. Defective diverter valve.	2. Replace valve.

3. Excessive engine idle rpm.	3. Adjust idle speed.
4. Choke setting too rich.	4. Lean out choke setting.
5. Defective choke.	5. Clean and adjust or replace.
6. Air pump inoperative.	6. (See air injection system inoperative.)

PROBLEM: ENGINE BACKFIRES IN INTAKE MANIFOLD

Possible Cause	Correction
1. Improper ignition timing or distributor dwell angle.	1. Adjust dwell and set timing as recommended.
2. Choke improperly adjusted.	2. Adjust choke.
3. Accelerator pump faulty or set too lean.	3. Repair, replace, or adjust as needed.

PROBLEM: ENGINE SURGES — ALL SPEEDS

Possible Cause	Correction
1. Carburetor defective or maladjusted.	1. Repair, replace, or adjust carburetor.
2. Defective anti-backfire valve.	2. Replace valve.

PROBLEM: ENGINE IDLES ROUGH

Possible Cause	Correction
1. Defective diverter valve or PCV valve.	1. Replace valve.
2. Anti-backfire vacuum line leaks.	2. Replace line or repair connection.
3. Carburetor defective or maladjusted.	3. Repair, replace, or adjust carburetor.
4. Improper ignition timing.	4. Set timing.
5. Fouled spark plugs, burned points, etc.	5. See chapter on Ignition System.
6. Faulty EGR valve operation.	6. Clean or replace unit. Check vacuum and vacuum lines.
7. EGR hoses misrouted.	7. Correct as required.
8. EGR valve gasket defective.	8. Replace gasket.
9. Improper EGR vacuum at idle.	9. Check vacuum source. Replace or repair as required.
10. Defective early fuel evaporation (EFE) valve (engine heat control valve).	10. Replace valve.
11 Defective altitude compensator.	11. Replace compensator.
12. No vacuum to early fuel evaporation valve.	12. Repair as required.

PROBLEM: ENGINE HESITATES ON ACCELERATION FOLLOWING FAST CLOSING OF THROTTLE VALVE

Possible Cause	Correction
1. Defective anti-backfire (diverter) valve.	1. Replace valve.
2. Anti-backfire valve vacuum line leaks.	2. Repair connections or replace hose.
3. Air outlet to intake manifold, from anti-backfire valve, leaking.	3. Repair connections or replace hose.
4. Defective early fuel evaporation valve.	4. Replace valve.
5. Malfunctioning EGR valve.	5. Replace EGR valve.
6. EGR hoses misrouted.	6. Route correctly.

PROBLEM: EGR VALVE STEM DOES NOT MOVE

Possible Cause	Correction
1. Defective valve.	1. Replace.
2. Dirty valve.	2. Clean.
3. Loose or damaged hose.	3. Connect or replace.
4. Stem frozen into position.	4. Clean or replace valve.
5. Defective coolant temperature switch.	5. Replace switch.
6. No vacuum to EGR valve.	6. Check EGR vacuum solenoid, EGR vacuum switch, vacuum regulator valve, vacuum pump, and hoses. Repair as required.
7. Defective thermal control valve.	7. Replace valve.
8. Defective control system—plugged passageways.	8. Clean out deposits.

PROBLEM: EXHAUST EMISSION LEVELS EXCESSIVE

Possible Cause	Correction
1. Fouled catalytic converter.	1. Replace catalyst or entire unit.
2. Rich fuel mixture.	2. Check choke, float bowl level, fuel pressure, clogged air filter, etc.
3. Faulty air injection system.	3. Check system. Adjust or repair as needed.
4. Stuck or inoperative EGR valve.	4. Clean or replace. Test.
5. Ignition timing off.	5. Check coolant temperature override switch action. Check transmission controlled spark advance. Check other spark advance units and control devices.
6. Inoperative or malfunctioning thermostatic air cleaner system.	6. Check system operation.
7. Faulty early fuel evaporation system.	7. Check system operation. Check thermal switch action.
8. Faulty electronic control module.	8. Test. Replace if faulty. Check wiring, connectors, etc.
9. Emission control units missing.	9. Replace with proper units. Retest.
10. Thermo sensor defective.	10. Replace sensor.
11. Defective spark plug(s).	11. Replace plugs.
12. Air leakage at idle.	12. Locate and correct.
13. Defective PCV valve.	13. Replace PCV valve.
14. Defective air control valve.	14. Replace valve.

KNOW THESE TERMS

Heat control valve, Resonator, Back pressure, Catalytic converter, Hydrocarbons (HC), Carbon monoxide (CO), Oxides of nitrogen (NOx), A.I.R., PCV, Thermactor, Carbon dioxide, Diverter valve, EGR, Back pressure transducer valve (BPV), Pintle, Coolant temperature override switch (CTO), Thermostatic air cleaner (TAC), Vacuum motor, Early fuel evaporation (EFE), Thermal sensor, "Ported" spark advance, Platinum, Palladium, Rhodium, Aluminum oxide beads, Ceramic substrate, Monolithic substrate, Charcoal canister, Vacuum amplifier, Vapor-liquid separator, Closed loop system, Pulse air, Electronic control module (ECM), Manifold absolute pressure sensor (MAP), Oxygen sensor.

QUIZ - Chapter 35

1. When composition exhaust manifold gaskets are used, the fasteners should be __________ following the first engine warm-up.
2. If exhaust manifold fasteners are properly tightened, locking devices are never needed. True or False?
3. The manifold heat control valve:
   a. Warms the gasoline coming to the carburetor.
   b. Warms the fuel charge in the intake manifold.
   c. Warms the air before entering the carburetor.
   d. Warms both air and gasoline before entering the carburetor.
4. List the four major parts of a typical exhaust system.
5. Exhaust systems are of the __________ or dual type.
6. Name three muffler designs.
7. Muffler life is extended by coating it with __________ or __________, or by making the muffler of __________ steel.
8. List six handy exhaust system tools.
9. When a joint is stuck, the application of __________ __________ and __________ will help to free it.
10. If the parts are not to be saved, the quickest way of freeing a stuck joint is to __________ the joint with a __________.
11. To provide additional insurance against leaks, it is wise to coat each joint with __________.
12. When inserting a tail or exhaust pipe either into or over a muffler nipple, the pipe should be shoved in or over:
    a. One third of the way.
    b. Halfway.
    c. The full nipple depth.
    d. Any of the above.
13. When installing a clamp on a joint, allow about __________ between the clamp and end of the pipe (or nipple) that it surrounds.
14. Exhaust pipe, tail pipe, and muffler size, as long as they fit, is relatively unimportant. True or False?
15. Before final tightening of exhaust system clamps and brackets, the system should be __________.
16. Following completion of work on the exhaust system, __________ the system for __________.
17. The deadly gas present in gasoline engine exhaust is called __________ __________.
18. The PCV system draws fumes from the __Engine__ back into the cylinders for __________.
19. Describe the operation of the air injection type of exhaust emission control system.
20. The emission control system reduces the amount of __CO__ discharged into the atmosphere and also reduces the amount of __________ __________ by changing much of it into __________ __________.
21. The air pump, in the air injection system, provides pressures of up to 30 psi (207 kPa). True or [✓ False]?
22. The air pump intake air is filtered by passing through a separate filter or by drawing the air

through the Intake air cleaner.

23. The check valve prevents pump air from entering the air manifold. True or [✓ False?]
24. In the AIR system, backfire in the exhaust system can be prevented by using either a ante back fire or a ______ valve.
25. When cleaning the check valve and the unit in Question 24, use compressed air to insure thorough cleaning. True or [✓ False?]
26. Before making emission control system tests, the engine should be at tenpeture operairating. Check all the hoses for leaks as well.
27. List five things, not a part of the air injection emission control system, that can reduce the effectiveness of the system.
28. How does the EGR valve function and what is its purpose?
29. Where used, what affect does the BPV have on the EGR valve action?
30. Of what use is the carbon canister on the evaporation control system? vapor storage
31. Describe the construction of a typical catalytic converter.
32. Catalytic converters require the use of unlead gasoline.
33. The catalyst in some converters can be replaced. True or False?
34. List three major pollutants found in the exhaust.

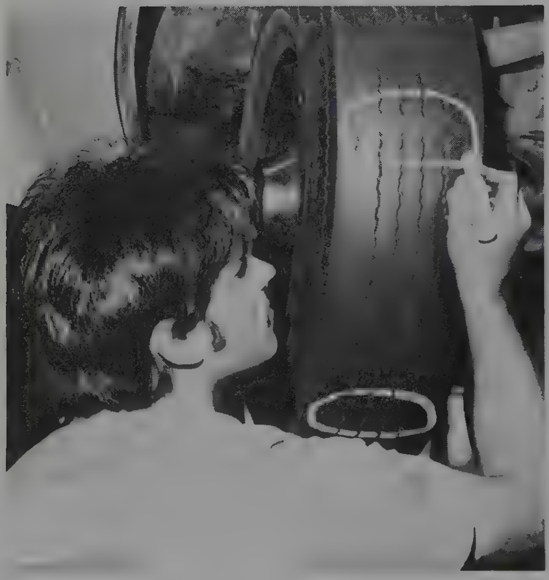
[illegible]

35. Why must catalytic converters have heat shielding?
36. List five things that can damage a catalytic converter. Lead misfire apen loop
37. Before attempting to diagnose emission problems, make certain the engine is in sound mechanical condition and is properly adjust.
38. Explain how a "closed loop" system functions.
39. The oxygen sensor is mounted in the:
    - a. Air horn.
    - b. Intake manifold.
    - [✓ c.] Exhaust system.
    - d. Radiator.
40. The exhaust Manifold Heat valve directs Hot gases to the intake manifold to aid in cold engine operation.
41. The unit in Question 40 may be operated by a: (Pick two)
    - a. Electric radiator.
    - [✓ b.] Bimetallic spring.
    - c. Hot water expansion tube.
    - [✓ d.] Vacuum motor.
42. A Termostatic Air Cleaned may be used to admit either warm or cold air to the carburetor air horn depending on engine and ambient temperature.
43. When a thermal sensor or thermal switch receives a sharp jolt by dropping on a hard surface, such as a cement floor, the unit should be replaced. [✓ True] or False?

Front end specialist utilizes a toe gauge in making alignment checks. (Ammco Tools)

DIAGNOSTIC COMPUTER
SAVE
GAS

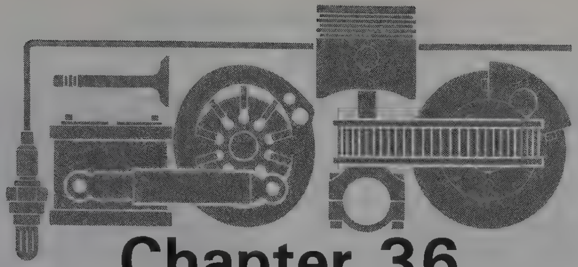
A diagnostic technician specializes in troubleshooting engine performance problems. (Sun Electric)



A tire sales and service expert calls a customer's attention to tire tread wear indicators that form smooth bands across tread of worn-out tire. (Firestone)

Product engineers confer on a design problem. (Central Foundry Div., GMC)

Engineers, diagnosticians, and service specialists are in great demand in the automotive field.



Chapter 36

CAREER OPPORTUNITIES IN THE AUTOMOTIVE FIELD

After studying this chapter, you will be able to:

☐ List jobs in automobile service and repair.
☐ Explain job makeup and working conditions.
☐ List addresses of various manufacturers that may offer helpful brochures, manuals, training courses, and other information on automotive careers.
☐ Explain the auto mechanics certification program.

TYPES OF JOBS AVAILABLE

In this chapter, we will discuss jobs in automotive maintenance and repair, as found in the modern garage or service center.

CLEANING

In cleaning, you will steam clean engines, other large assemblies, or maybe the under body portion of the car. You will wash, and often wax, the exterior finish. Vacuuming, window and upholstery cleaning and the installation of seat covers might be your job.

Part of your day may be spent in the delivery and moving of cars. Occasionally, you might assist the mechanics, parts specialist, or other personnel.

Your work in the cleaning department will let you demonstrate your ability as a hard working and responsible person. There will be plenty of chances to observe the work in other areas. Coupled with additional study, you can prepare yourself for advancement. When ready, you may move from the cleaning to the lubrication department.

LUBRICATION

Lubrication involves lubricating the working parts of the car, checking oil levels in the engine, transmission, differential, etc. It includes inspection of the battery, master cylinder, radiator, steering system, brake system, and other parts critical to the safe operation of the car.

Work in this area will provide an opportunity to learn a great deal about the various systems on the car. It will pave the way to advancement toward more complicated mechanical service.

MECHANIC — LIGHT REPAIR

Part of the work as a light repair mechanic usually consists of checking out new cars before delivery. You will go over the entire car to make certain that all systems are functioning and are in proper adjustment.

You will probably assist with checkups required by manufacturers' warranties.

Training in this job, even though it generally involves minor repair and adjustment, is invaluable. It will prepare you for the more complicated heavy repair work, or for that matter, in some specialty, such as tune-up, brakes, etc.

MECHANIC — HEAVY REPAIR

In the heavy repair department, you will service, dismantle, check, repair, reassemble, and check engines, transmissions, differentials, and other major units. This job will require a great deal of study, practice, and experience.

At first, you will probably work under a qualified, experienced mechanic in this area. Your success will depend upon your aptitude (natural ability), interest, ambition, and a sincere desire to learn.

Once having mastered the work involved, you will be a valuable asset in any garage. You will have placed yourself in a good position for advancement. See Fig. 36-1.

SPECIALIZATION

Every new model year, automobiles have new devices and special features. It is becoming more and more difficult for a mechanic to master the service and

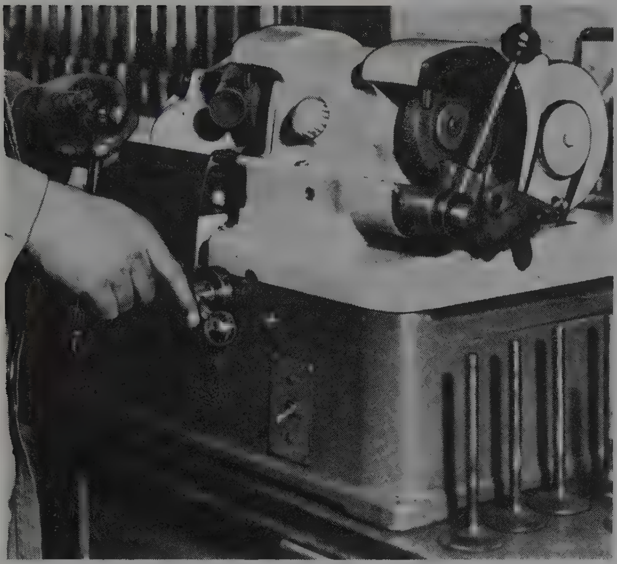


Fig. 36-1. Mechanic refacing valves. (Thor)

repair of the entire car. If the volume of work permits, specialization in one area will provide the customer with faster and more efficient service. The mechanic handling the job will be a specialist in that particular area.

The specialist will have advanced and concentrated training and experience in a chosen specialty. Full time work in one area will help the specialist become highly proficient.

TUNE-UP SPECIALIST

The tune-up specialist will handle jobs involving ignition system service, fuel injection service, carburetor cleaning, adjusting, and checking. Alternator and starter work as well as electrical wiring, headlights, etc., will also be in this field.

Tune-up work requires a high level of competency. It is a good paying job and will provide an excellent chance for further advancement, Fig. 36-2.

BRAKE SPECIALIST

The brake specialist does such work as disc and drum turning, lining installation and truing, shoe adjustment, master and wheel cylinder repair, bleeding, and line replacement. Special training in brake trouble diagnosis and power brake units is required.

TRANSMISSION SPECIALIST

The transmission mechanic will handle transmission work, both standard and automatic. Necessary skills include testing, diagnosis, disassembly, checking, repair, and reassembly of transmissions. The transmission specialist must have a thorough background in the fundamentals as well as special training in this field. See Fig. 36-3.

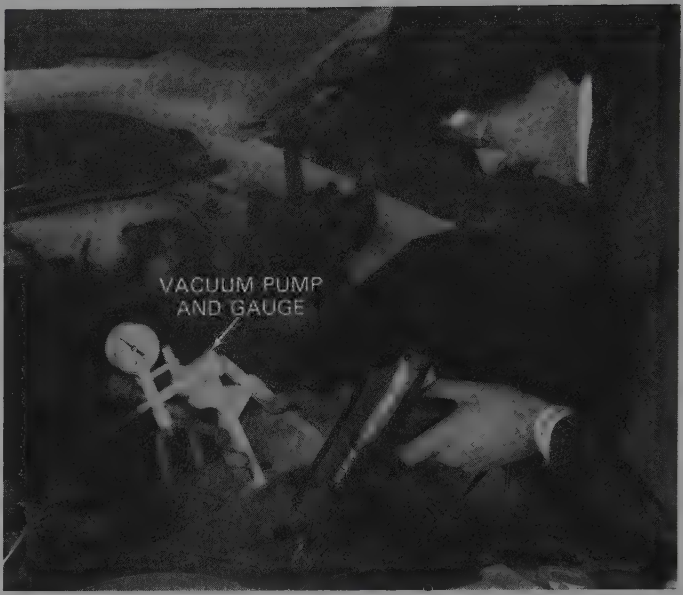


Fig. 36-2. Tune-up specialist checking distributor vacuum advance operation using a power timing light and hand vacuum pump. (OTC)

FRONT END SPECIALIST

Wheel balancing and alignment, and work on the steering gearbox, steering linkage, spindles, springs,

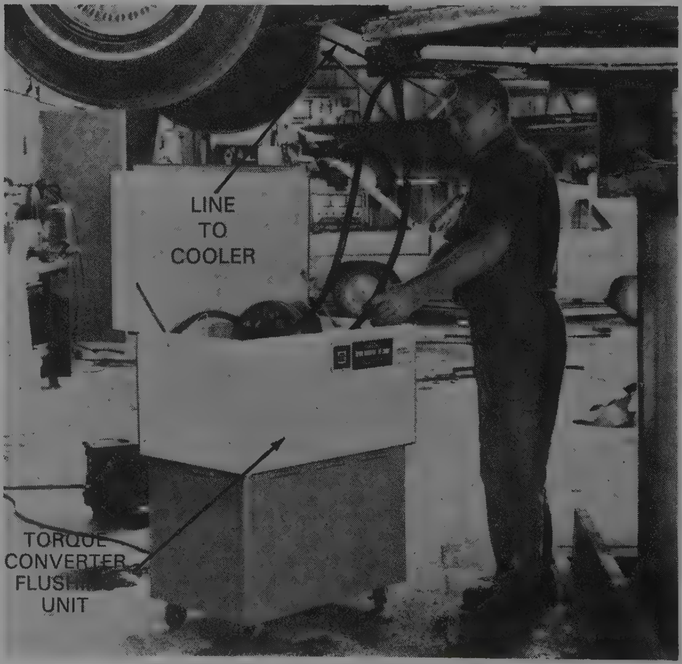


Fig. 36-3. Transmission specialist using a torque converter flushing unit to clean out converter and transmission cooler. (OTC)

and control arms is done by the front end specialist. It is this particular mechanic's duty to see that the car steers and handles easily and safely, and that the tires run smoothly and wear properly.

ELECTRICAL SPECIALIST

The modern car makes wide use of electrical units. The electrical specialist will handle work on such items as radios, CB sets, electric seats, window operating devices, fuel injection units, instruments, alternators, starters, etc. This job requires an extensive knowledge of electricity as well as the repair and adjustment of all electrical units.

AIR CONDITIONING SPECIALIST

The air conditioning specialist's job involves checking, adjusting, and repairing the car air conditioning system. There are many jobs for mechanics with special training in this area.

BODY AND FENDER SPECIALIST

Body and fender work, although separate from mechanical repair, is an important part of a garage's work.

The body and fender mechanic will repair damage to the car's metal structure, the upholstering, and inside trim. The body and fender specialist will install glass, repair locks, handles, etc. This job requires proficiency in cutting, welding, metal bumping, filling, priming, painting, etc. Within the field of body and fender work, the actual painting is rapidly becoming a specialty of its own. Look at Fig. 36-4.

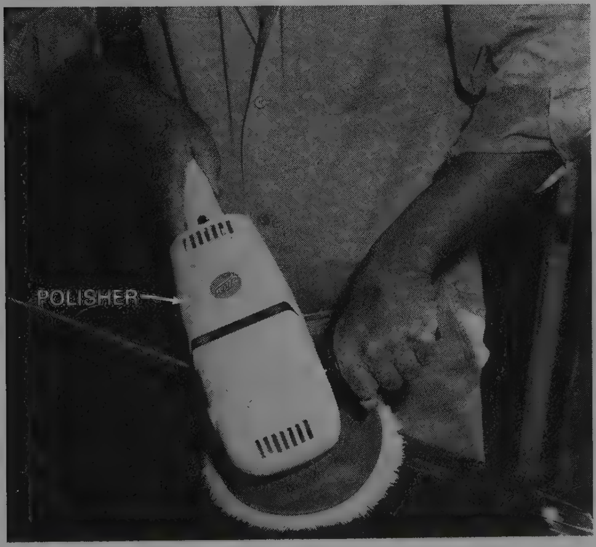


Fig. 36-4. Body specialist polishing a vehicle fender following refinishing and painting. (Thor Tools)

SUB-SPECIALISTS

In some large garages, mechanics specialize within a specialty or they become sub-specialists. In a specialized area, the work can become involved enough to provide full time work on specific units within the speciality.

SUPERVISORIAL POSITIONS

Most mechanics, entering a particular field, look forward to advancement in pay and position. This is as it should be, both in the garage and service station fields, as in many other fields.

Advancement is dependent on your knowledge and skill, as well as a demonstration of your ability to cope with the problems of the position.

SHOP SUPERVISOR

The shop supervisor is in charge of the mechanics in the repair department. The supervisor is held directly responsible for the work turned out by the mechanics. This calls for a highly competent mechanic familiar with and able to perform all jobs that enter the shop.

In larger garages, the supervisor's time will be spent directing the mechanics, checking their work, giving suggestions, and in general, seeing that the shop runs smoothly and efficiently. In a small garage, the supervisor may spend part of the day doing repair work, with the remainder of the time devoted to supervision.

SERVICE MANAGER

The service manager holds a very responsible position. This title is held by the person in charge of the overall garage service operation. The service manager must see that customers get prompt, efficient, and fair priced service. Customers must be pleased and mechanics and others in the department must be satisfied and doing good work.

The service manager's job usually entails the handling of employee training programs. This requires close cooperation with factory representatives to see that the latest and best service techniques are employed.

The service manager must have an insight into the job itself. This calls for leadership ability, a good personality, training, knowledge, and the ability to work with others. Being a service manager is not an easy job, but it certainly is a worthwhile ambition.

Other jobs found in the modern garage, in addition to those discussed, are shown on the dealer organization chart, Fig. 36-5.

SMALL GARAGE MECHANIC

The mechanic working in a small garage will be called upon to meet customers, diagnose their problems, make

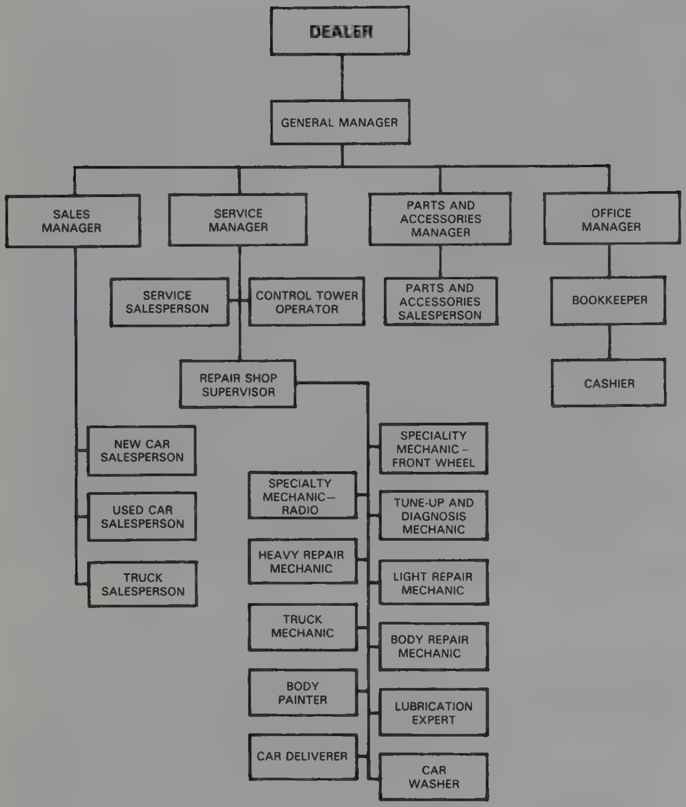

DEALER
GENERAL MANAGER
SALES MANAGER
SERVICE MANAGER
PARTS AND ACCESSORIES MANAGER
OFFICE MANAGER
SERVICE SALESPERSON
CONTROL TOWER OPERATOR
PARTS AND ACCESSORIES SALESPERSON
BOOKKEEPER
REPAIR SHOP SUPERVISOR
CASHIER
NEW CAR SALESPERSON
USED CAR SALESPERSON
TRUCK SALESPERSON
SPECIALITY MECHANIC – FRONT WHEEL
SPECIALTY MECHANIC – RADIO
TUNE-UP AND DIAGNOSIS MECHANIC
HEAVY REPAIR MECHANIC
LIGHT REPAIR MECHANIC
TRUCK MECHANIC
BODY REPAIR MECHANIC
BODY PAINTER
LUBRICATION EXPERT
CAR DELIVERER
CAR WASHER

Fig. 36-5. This chart will give you an idea of how a modern automobile dealership is organized.

cost estimates for work to be done, and prepare billings for finished jobs. Training is required in all aspects of mechanical work done in the garage.

WORKING CONDITIONS — SALARY

The garage of today is a far cry from the crowded, dark, cold, and poorly ventilated garage of yesterday. The modern garage is well lighted, roomy, and provides a pleasing place in which to work.

Many garages feature lunchrooms, showers, lockers, etc., for their employees. The addition of heavy power equipment has removed much of the sheer labor involved, and also provides easier and more comfortable access to the various parts of the car.

Most mechanics work inside, but when a job incorporates roadside repair, the mechanic may be faced with varying weather conditions.

Many mechanics, especially those in urban areas and in large garages, belong to one of several unions. Among the unions are the International Association of Machinists; the International Union; the International Brotherhood of Teamsters, Chauffers, Warehousemen, and Helpers of America; the United Automobile, Aircraft, and Agricultural Implement Workers of America.

It is difficult to say what salary you can expect. Much depends on the type of work performed, location (geographical) of the job, employer, prevailing business conditions, and job supply and demand. All exert a definite influence on the mechanic's salary.

Most mechanics earn a good living. Their salaries are in line with other types of technical jobs.

Many auto mechanics receive a certain percentage of the customer labor charge. As the rates for various jobs are fixed, the skilled mechanic will be able to do more jobs in one day than the unskilled mechanic, and as a result, will earn more money.

AVAILABILITY OF EMPLOYMENT

The increasing use of cars, plus the addition of more complex items on the car, has provided a lucrative field for qualified mechanics. If you really learn the trade and are a hard working, conscientious person, you should be able to readily find employment.

Many small self-owned shops have been started by mechanics. Many service stations offer light duty repair and employment possibilities.

About a third of all mechanics work in new and used car dealer garages. Another third work in repair shops that specialize in a multitude of automotive repairs such as body and fender work, tune-up, brake, front end, radiator work, etc. Other mechanics work for large fleet owners such as the utility companies, dairies, produce companies, and federal, state, county, and city organizations.

WOULD YOU DO WELL AND WOULD YOU BE SATISFIED IN THIS FIELD?

If you are sincerely interested in cars, enjoy working on and studying about cars, and are in normal health, the chances are good that you will like this work and do well in it.

HOW DOES A PERSON BECOME AN AUTO MECHANIC?

A person develops into a good auto mechanic by study, observation, instruction, and experience.

High schools, trade schools, the Armed Forces, factory and apprentice programs, all offer excellent opportunities to acquire the training necessary to gain employment in this field.

Another area offering training in the automotive field is the Job Corps. Job Corps is a training program for men and women between 16 and 21. Many trades in addition to auto mechanics are taught.

The training centers provide essential materials such as medical and dental care, books, etc.

For information on joining the Job Corps, see your local State Employment Service or write to:

U.S. Department of Labor
Manpower Administration, Job Corps
Washington, DC 20210

The following list of vehicle manufacturers and importers may be able to furnish you with educational booklets, brochures, manuals, etc. Some items may be offered free of charge while others may carry a nominal fee. For materials of this type, direct your request to the MANAGER, EDUCATIONAL PUBLICATIONS DEPARTMENT, of the company in which you are interested.

Training programs and job placement information may also be offered. For this type of information, address: MANAGER, PERSONNEL, and/or TRAINING DEPARTMENT.

BMW OF NORTH AMERICA, INC.
Montvale, NJ 07645

CHRYSLER CORPORATION
College Graduates:
College Recruitment Services
Personnel Department
Chrysler Corporation
Chrysler Center
P.O. Box 1919
Detroit, MI 48288

High School, Vocational School Graduates:
Manager, Personnel Department
Chrysler Corporation
Chrysler Center
P.O. Box 1919
Detroit, MI 48288

FIAT AUTO U.S.A., INC.
777 Terrace Avenue
Hasbrouch Heights, NJ 07604

FORD MOTOR COMPANY
Placement and College Recruitment
Ford Motor Company
The American Road
Dearborn, MI 48121

GENERAL MOTORS CORPORATION
Salaried Placement Personnel
General Motors Corporation
General Motors Building
Detroit, MI 48202

HONDA MOTOR CO.
100 W. Alondra
Gardena, CA 90247

MAZDA MOTORS OF AMERICA
8313 Baycenter Road
Jacksonville, FL 32216

MERCEDES-BENZ OF NORTH AMERICA, INC.
One Mercedes Drive
Montvale, NJ 07645

MITSUBISHI MOTOR SALES OF AMERICA, INC.
10540 Talbert Street
Fountain Valley, CA 92728-9060

NISSAN MOTOR MANUFACTURING CO., USA
18501 Figueroa Street
Carson, CA 90248

PEUGEOT MOTORS OF AMERICA, INC.
One Peugeot Plaza
Lyndhurst, NJ 07071

PORSCHE
200 S. Virginia
Reno, NV 89501

SAAB-SCANIA OF AMERICA, INC.
Saab Drive
Orange, CT 06477

SUBARU OF AMERICA, INC.
P.O. Box 6000
Pennsauken, NJ 08034-6000

TOYOTA MOTOR SALES USA, INC.
19001 S. Western Ave.
Torrance, CA 90509

VOLKSWAGEN OF AMERICA, INC.
888 W. Big Beaver Road
P.O. Box 3951
Troy, MI 48099

VOLVO NORTH AMERICA CORPORATION
Rockleigh, NJ 07647

ADDITIONAL INFORMATION

The following is a list of related automobile industry associations which may also provide interesting and informative materials.

A good collection of pamphlets, brochures, training manuals, and other materials will form the basis for a very useful library. Remember, that today, as always, LEARNING and EARNING go hand in hand.

Address: MANAGER, EDUCATIONAL MATERIALS DEPARTMENT:

AMERICAN PETROLEUM INSTITUTE
1220 L Street N.W.
Washington, DC 20037

AUTOMOTIVE SAFETY FOUNDATION
1776 Massachusetts Avenue N.W.
Washington, DC 20036

BATTERY COUNCIL INTERNATIONAL
111 East Wacker Drive
Chicago, IL 60601

EQUIPMENT AND TOOL INSTITUTE
1545 Waukegan Road
Glenview, IL 60025

MOTOR AND EQUIPMENT MANUFACTURERS ASSOCIATION
300 Sylvan Ave.
Englewood Cliffs, NJ 07632

MOTOR VEHICLE MANUFACTURERS ASSOCIATION OF THE U.S., INC.
300 New Center Building
Detroit, MI 48202

NATIONAL AUTOMOBILE DEALERS ASSOC.
1400 K Street N.W.
Washington, DC 20005

RUBBER MANUFACTURERS ASSOCIATION
1901 Pennsylvania Avenue
Washington, DC 20006

CERTIFICATION

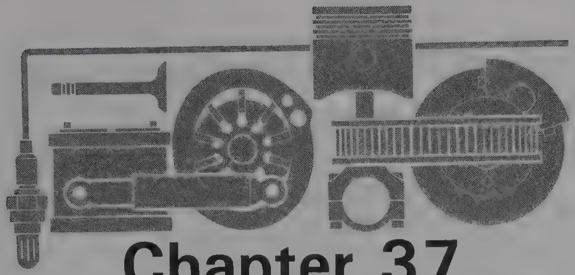
The National Institute for Automotive Service Excellence (ASE) Certification Program offers a practical method to provide qualified technicians with the recognition and improved status they deserve. The ASE provides tests and certifications in automobile repair, heavy-duty truck (and bus) repair, body repair, and in refinishing and painting.

You may receive credit for school shop work. You can wear your ASE patch with honest pride. For more information, write:

NATIONAL INSTITUTE FOR AUTOMOTIVE SERVICE EXCELLENCE
13505 Dulles Technology Drive
Herndon, VA 22071-3415

KNOW THESE TERMS

Light repair, Heavy repair, Tune-up specialist, Brake specialist, Shop supervisor, Service manager, NIASE, Air conditioning specialist.



Chapter 37

MANUALS, REPAIR ORDERS, COST ESTIMATES, METRIC TABLES

After studying this chapter, you will be able to:

☐ Explain how to use service manuals.
☐ Fill out a repair order.
☐ Complete cost esimates for repairs.
☐ Use metric tables.

This chapter summarizes the use of service manuals, repair orders, and metric tables. Service manuals are essential "tools" of the mechanic. They will answer questions about diagnosis, give detailed steps for repairs, and list specifications. Repair orders tell the mechanic about the car's problem and the needed repair. They also provide a record for billing the customer. Metric tables allow you to convert a conventional value to a metric value and vice versa.

Note! This is an important chapter that will help you develop important skills needed for many positions in auto repair. Study carefully!

SERVICE MANUALS

Service manuals, also called workshop manuals, shop manuals, and unit repair manuals, are books that supply technical information covering the service and repair of a particular vehicle or component. The manuals also contain helpful step-by-step instructions, diagrams, illustrations, and troubleshooting charts.

Service manuals come in various types. Manufacturers manuals, also called factory service manuals, are printed by the automobile makers. Other specialized manuals (covering individual areas such as engines, transmissions, ignitions), and general repair manuals (offering general diagnosing and repairing information) are published by both automobile makers and various automotive book publishers. They usually cover several different vehicle makes, models, and years. They are particularly useful for independent garages that work on a wide variety of cars.

USING SERVICE MANUALS

The use of manuals is greatly simplified by following these guidelines.

1. Select the right manual for the vehicle being repaired.
2. Use the table of contents or index to locate the component to be worked on. Some manuals will have the content sections (engines, transmissions, etc.), broken into subsections to further help you find the needed information.
3. Before beginning a repair, read all material carefully. Be aware of safety rules and special tools required. Study all illustrations.
4. Start repair. Follow all instructions (tool use, torque specs, etc.).
5. Return manual when finished. If you noticed any errors in the manual, fill in the manual comment or errors form and return it to the manufacturer. Make note of such error in the manual itself.

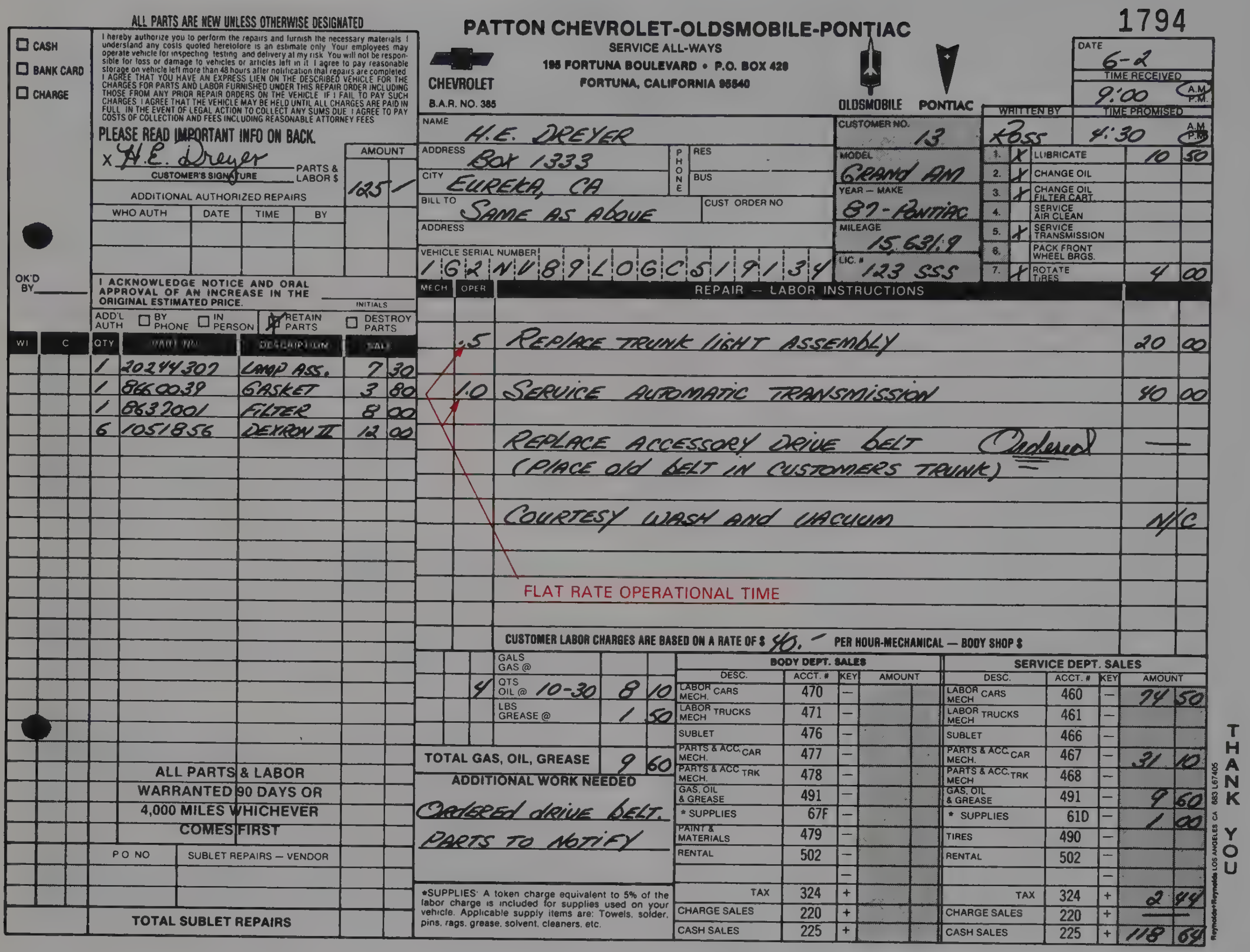
REPAIR ORDERS

Repair orders, also termed shop work orders, invoices, or warranty orders, are used to keep a record of vehicle service, repair, and warranty work. See Figs. 37-1 and 37-2.

The repair order or warranty order is partially completed by the Service Manager, Service Writer, or Shop Manager. That person fills in the customer's name, address, telephone number, vehicle information (make, model, year, mileage, etc.). The customer's problem is also listed to aid the mechanic or service technician.

If the customer complained of a cold start driveability problem for example, this will provide the mechanic with a general starting point.

An estimate of the anticipated repair costs are shown



ALL PARTS ARE NEW UNLESS OTHERWISE DESIGNATED

☐ CASH
☐ BANK CARD
☐ CHARGE

I hereby authorize you to perform the repairs and furnish the necessary materials. I understand any costs quoted heretofore is an estimate only. Your employees may operate vehicle for inspecting, testing, and delivery at my risk. You will not be responsible for loss or damage to vehicles or articles left in it. I agree to pay reasonable storage on vehicle left more than 48 hours after notification that repairs are completed. I AGREE THAT YOU HAVE AN EXPRESS LIEN ON THE DESCRIBED VEHICLE FOR THE CHARGES FOR PARTS AND LABOR FURNISHED UNDER THIS REPAIR ORDER INCLUDING THOSE FROM ANY PRIOR REPAIR ORDERS ON THE VEHICLE. IF I FAIL TO PAY SUCH CHARGES, I AGREE THAT THE VEHICLE MAY BE HELD UNTIL ALL CHARGES ARE PAID IN FULL. IN THE EVENT OF LEGAL ACTION TO COLLECT ANY SUMS DUE, I AGREE TO PAY COSTS OF COLLECTION AND FEES INCLUDING REASONABLE ATTORNEY FEES

PLEASE READ IMPORTANT INFO ON BACK.

x H.E. Dreyer
CUSTOMER'S SIGNATURE

PARTS & LABOR $ — AMOUNT: 125 —

ADDITIONAL AUTHORIZED REPAIRS

WHO AUTH	DATE	TIME	BY	AMOUNT

OK'D BY ______

I ACKNOWLEDGE NOTICE AND ORAL APPROVAL OF AN INCREASE IN THE ORIGINAL ESTIMATED PRICE. ______ INITIALS

ADD'L AUTH ☐ BY PHONE ☐ IN PERSON ☒ RETAIN PARTS ☐ DESTROY PARTS

WI	C	QTY	PART NO.	DESCRIPTION	SALE
		1	20244307	LAMP ASS.	7 30
		1	8660039	GASKET	3 80
		1	8637001	FILTER	8 00
		6	1051856	DEXRON II	12 00

ALL PARTS & LABOR WARRANTED 90 DAYS OR 4,000 MILES WHICHEVER COMES FIRST

P O NO	SUBLET REPAIRS — VENDOR	
	TOTAL SUBLET REPAIRS	

PATTON CHEVROLET-OLDSMOBILE-PONTIAC
SERVICE ALL-WAYS
195 FORTUNA BOULEVARD • P.O. BOX 428
FORTUNA, CALIFORNIA 95540
CHEVROLET
B.A.R. NO. 385
OLDSMOBILE PONTIAC

1794

DATE: 6-2
TIME RECEIVED: 9:00 [✓ A.M.] P.M.
WRITTEN BY: Ross
TIME PROMISED: 4:30 A.M. [✓ P.M.]

NAME: H.E. DREYER
ADDRESS: Box 1333
CITY: EUREKA, CA
PHONE: RES / BUS
BILL TO: SAME AS ABOVE
CUST ORDER NO
ADDRESS
VEHICLE SERIAL NUMBER: 1 G 2 N V 8 9 L 0 G C 5 1 9 1 3 4
CUSTOMER NO.: 13
MODEL: GRAND AM
YEAR — MAKE: 87-PONTIAC
MILEAGE: 15,631.9
LIC. #: 123 SSS

1.	X	LUBRICATE	10	50
2.	X	CHANGE OIL		
3.	X	CHANGE OIL FILTER CART.		
4.		SERVICE AIR CLEAN		
5.	X	SERVICE TRANSMISSION		
6.		PACK FRONT WHEEL BRGS.		
7.	X	ROTATE TIRES	4	00

MECH	OPER	REPAIR — LABOR INSTRUCTIONS		
	.5	REPLACE TRUNK LIGHT ASSEMBLY	20	00
	1.0	SERVICE AUTOMATIC TRANSMISSION	40	00
		REPLACE ACCESSORY DRIVE BELT Ordered	—	
		(PLACE old BELT IN CUSTOMERS TRUNK)		
		COURTESY WASH AND VACUUM	N/C	

FLAT RATE OPERATIONAL TIME

CUSTOMER LABOR CHARGES ARE BASED ON A RATE OF $ 40.— PER HOUR-MECHANICAL — BODY SHOP $

GALS GAS @		
4 QTS OIL @ 10-30	8	10
LBS GREASE @	1	50
TOTAL GAS, OIL, GREASE	9	60

ADDITIONAL WORK NEEDED
ORDERED DRIVE BELT.
PARTS TO NOTIFY

*SUPPLIES: A token charge equivalent to 5% of the labor charge is included for supplies used on your vehicle. Applicable supply items are: Towels, solder, pins, rags, grease, solvent, cleaners, etc.

BODY DEPT. SALES

DESC.	ACCT. #	KEY	AMOUNT
LABOR MECH. CARS	470	—	
LABOR MECH TRUCKS	471	—	
SUBLET	476	—	
PARTS & ACC. MECH. CAR	477	—	
PARTS & ACC. MECH. TRK	478	—	
GAS, OIL & GREASE	491	—	
* SUPPLIES	67F	—	
PAINT & MATERIALS	479	—	
RENTAL	502	—	
		—	
TAX	324	+	
CHARGE SALES	220	+	
CASH SALES	225	+	

SERVICE DEPT. SALES

DESC.	ACCT. #	KEY	AMOUNT
LABOR MECH CARS	460	—	74 50
LABOR MECH TRUCKS	461	—	
SUBLET	466	—	
PARTS & ACC. MECH. CAR	467	—	31 10
PARTS & ACC. MECH TRK	468	—	
GAS, OIL & GREASE	491	—	9 60
* SUPPLIES	610	—	1 00
TIRES	490	—	
RENTAL	502	—	
		—	
TAX	324	+	2 44
CHARGE SALES	220	+	—
CASH SALES	225	+	118 64

THANK YOU

Reynolds+Reynolds LOS ANGELES CA 683 L67405

Fig. 37-1. One type of shop repair order. Study the various sections and general layout.

to the customer. If he or she agrees to the cost, the repair order is then given to a mechanic to be used for diagnosing, testing, and correcting the problem. If costs will exceed the estimate, the customer should be notified and give permission for the increased cost prior to completing the job.

At the beginning of the repair job, the mechanic will write or punch in the time started, and will do the same when finished, allowing for time off for lunch, breaks, other jobs, etc.

When the defective part(s) are replaced, they are written in the space provided. The part number, description (new, used, rebuilt), and price, is also included.

After the repair is complete, labor time is computed. If the repair involved three hours of labor, and the shop charged $40.00 per hour, the labor charge would be $120.00 (40.00 × 3). Next, the part prices are totaled along with taxes. These when combined, give the customer's total bill.

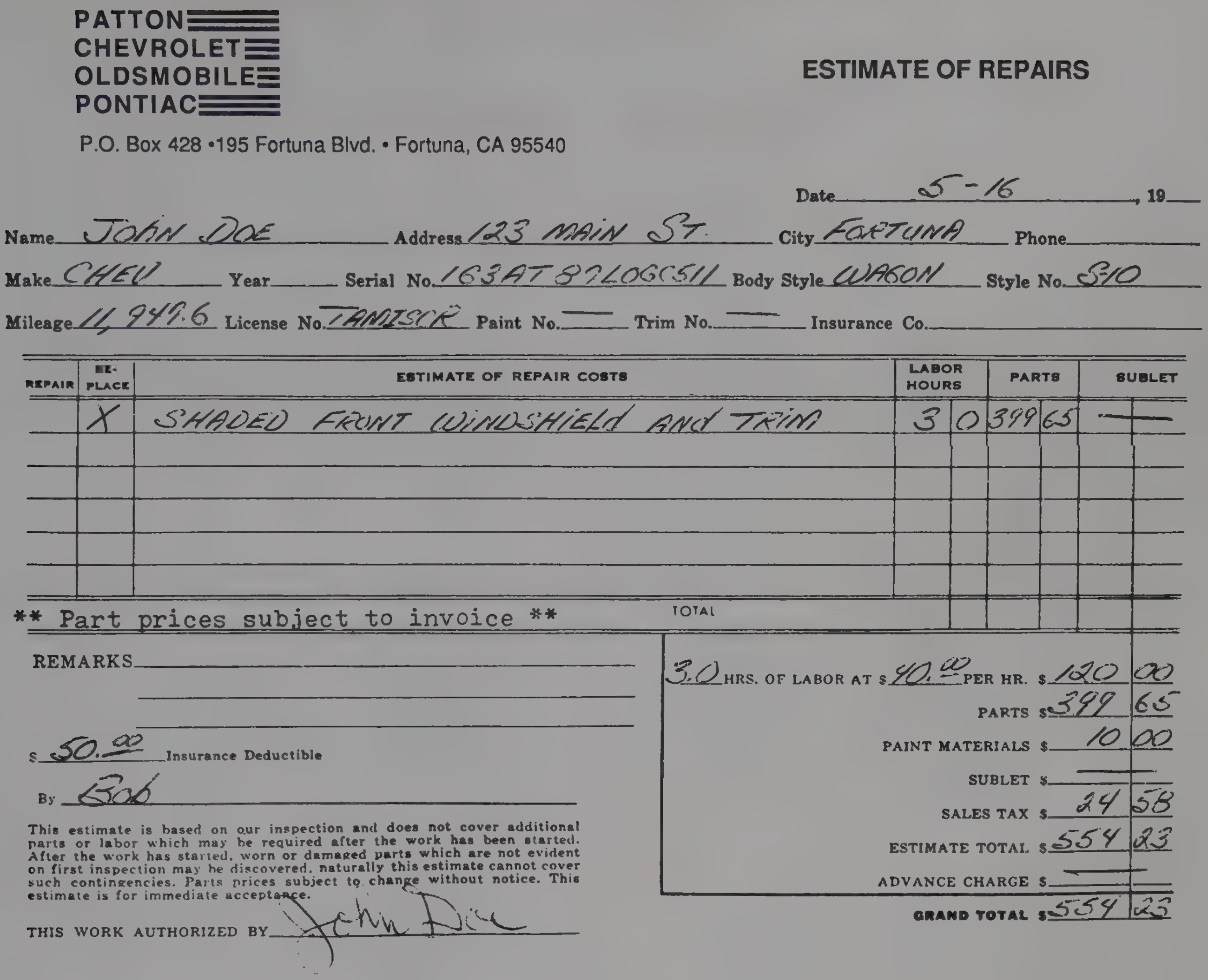
One or two copies of the repair order are given to the customer. The remaining ones are retained by the shop for records.

Warranty repair orders are generally completed in the same manner as standard repair orders. The customer also receives a copy of this order, but is not usually billed for costs.

Be sure to fill in all necessary boxes neatly and correctly. This provides that added "professional look" to your overall work.

LABOR COST ESTIMATING

Most shops or garages use one of two methods to determine correct labor costs. The first uses a shop's hourly rate (amount charged per hour of mechanic's time). Hours of repair times the labor rate equals cost.



PATTON
CHEVROLET
OLDSMOBILE
PONTIAC

P.O. Box 428 •195 Fortuna Blvd. • Fortuna, CA 95540

ESTIMATE OF REPAIRS

Date 5-16, 19__

Name JOHN DOE Address 123 MAIN ST. City FORTUNA Phone ____

Make CHEV Year ____ Serial No. 163AT87LOGC511 Body Style WAGON Style No. S10

Mileage 11,949.6 License No. 7AMISCR Paint No. — Trim No. — Insurance Co. ____

REPAIR	RE-PLACE	ESTIMATE OF REPAIR COSTS	LABOR HOURS		PARTS		SUBLET	
	X	SHADED FRONT WINDSHIELD AND TRIM	3	0	399	65	—	
		TOTAL						

`** Part prices subject to invoice **`

REMARKS ____

3.0 HRS. OF LABOR AT $ 40.00 PER HR.	$ 120	00
PARTS	$ 399	65
PAINT MATERIALS	$ 10	00
SUBLET	$ —	
SALES TAX	$ 24	58
ESTIMATE TOTAL	$ 554	23
ADVANCE CHARGE	$ —	
GRAND TOTAL	$ 554	23

$ 50.00 Insurance Deductible

By Bob

This estimate is based on our inspection and does not cover additional parts or labor which may be required after the work has been started. After the work has started, worn or damaged parts which are not evident on first inspection may be discovered, naturally this estimate cannot cover such contingencies. Parts prices subject to change without notice. This estimate is for immediate acceptance.

THIS WORK AUTHORIZED BY John Doe

Fig. 37-2. One type of body shop repair order.

If the repair took two hours, and the hourly labor rate is $40.00, the bill would be $80.00 (40.00 × 2).

The other method uses the flat rate manual. This manual gives an estimate of how much time the mechanic should need to complete certain repairs. If the mechanic is to replace a set of spark plugs, he or she simply looks for plug replacement covering the particular engine. The manual may indicate one hour for the job. Again, hours times labor rate will give the cost (1 hour × 40.00 equals $40.00). Generally, if the plug replacement or other job is slow and takes two hours, the customer is only required to pay the flat rate amount. This prevents overcharging.

Some shops will pay the mechanic, in addition to the regular hourly wage, the difference between flat rate time and actual repair time if repair time is less than the quoted flat rate. This allows a fast mechanic to earn more per hour.

PART COST ESTIMATING

When estimating part costs on a repair order, a percentage increase is generally added to the wholesale (jobber price) of each part. Prices will vary with suppliers and brand names. The percentage increase is added before the estimate is given to the customer for approval. The percentage is added to cover the shop's cost for handling the part, paperwork, and margin of profit.

TAX CHARGE CALCULATING

To compute the tax charge on a repair job, multiply the tax rate by the total parts cost. For example, if the parts cost $75.00 and your state tax rate is 6%, multiply $75.00 by .06 (75.00 × .06 = 4.50). With a tax of $4.50, parts equaling $75.00, the parts subtotal would be $79.50. Add $79.50 to labor costs for your final total for the job. When making these computations, add any other applicable taxes (city and state) that may apply in your area.

ALWAYS, without fail, bill customers ACCURATELY and HONESTLY. The finest advertisement for any shop, and mechanic, is scrupulous honesty at all times.

METRIC TABLES

SOME COMMON ABBREVIATIONS/SYMBOLS

ENGLISH		METRIC	
UNIT	ABBREVIATION	UNIT	SYMBOL
inch	in	kilometre	km
feet	ft	hectometre	hm
yard	yd	dekametre	dam
mile	mi	metre	m
grain	gr	decimetre	dm
ounce	oz	centimetre	cm
pound	lb	millimetre	mm
teaspoon	tsp	cubic centimetre	cm^3
tablespoon	tbsp	kilogram	kg
fluid ounce	fl oz	hectogram	hg
cup	c	dekagram	dag
pint	pt	gram	g
quart	qt	decigram	dg
gallon	gal	centigram	cg
cubic inch	in^3	milligram	mg
cubic foot	ft^3	kilolitre	kl
cubic yard	yd^3	hectolitre	hl
square inch	in^2	dekalitre	dal
square foot	ft^2	litre	L
square yard	yd^2	centilitre	cl
square mile	mi^2	millilitre	ml
Fahrenheit	F	dekastere	das
barrel	bbl	square kilometre	km^2
fluid dram	fl dr	hectare	ha
board foot	bd ft	are	a
rod	rd	centare	ca
dram	dr	tonne	t
bushel	bu	Celsius	C

MEASURING SYSTEMS

ENGLISH	METRIC
LENGTH	
12 inches = 1 foot	1 kilometre = 1000 metres
36 inches = 1 yard	1 hectometre = 100 metres
3 feet = 1 yard	1 dekametre = 10 metres
5,280 feet = 1 mile	1 metre = 1 metre
16.5 feet = 1 rod	1 decimetre = 0.1 metre
320 rods = 1 mile	1 centimetre = 0.01 metre
6 feet = 1 fathom	1 millimetre = 0.001 metre
WEIGHT	
27.34 grains = 1 dram	1 tonne = 1,000,000 grams
438 grains = 1 ounce	1 kilogram = 1000 grams
16 drams = 1 ounce	1 hectogram = 100 grams
16 ounces = 1 pound	1 dekagram = 10 grams
2000 pounds = 1 short ton	1 gram = 1 gram
2240 pounds = 1 long ton	1 decigram = 0.1 gram
25 pounds = 1 quarter	1 centigram = 0.01 gram
4 quarters = 1 cwt	1 milligram = 0.001 gram
VOLUME	
8 ounces = 1 cup	1 hectolitre = 100 litres
16 ounces = 1 pint	1 dekalitre = 10 litres
32 ounces = 1 quart	1 litre = 1 litre
2 cups = 1 pint	1 decilitre = 0.1 litre
2 pints = 1 quart	1 centilitre = 0.01 litre
4 quarts = 1 gallon	1 millilitre = 0.001 litre
8 pints = 1 gallon	1000 millilitre = 1 litre
AREA	
144 sq. inches = 1 sq. foot	100 sq. millimetres = 1 sq. centimetre
9 sq. feet = 1 sq. yard	100 sq. centimetres = 1 sq. decimetre
43,560 sq. ft. = 160 sq. rods	100 sq. decimetres = 1 sq. metre
160 sq. rods = 1 acre	10,000 sq. metres = 1 hectare
640 acres = 1 sq. mile	

TEMPERATURE

FAHRENHEIT		CELSIUS
32 degrees F	Water freezes	0 degree C
68 degrees F	Reasonable room temperature	20 degrees C
98.6 degrees F	Normal body temperature	37 degrees C
173 degrees F	Alcohol boils	78.34 degrees C
212 degrees F	Water boils	100 degrees C

USEFUL CONVERSIONS

WHEN YOU KNOW:	MULTIPLY BY:	TO FIND:
	TORQUE	
Pound - inch	0.11298	newton-metres (N-m)
Pound - foot	1.3558	newton-metres
	LIGHT	
Foot candles	1.0764	lumens/metres^2 (lm/m^2)
	FUEL PERFORMANCE	
Miles/gallon	0.4251	kilometres/litre (km/L)
	SPEED	
Miles/hour	1.6093	kilometres/hr (km/h)
	FORCE	
kilogram	9.807	newtons (n)
ounce	0.278	newtons
pound	4.448	newtons
	POWER	
Horsepower	0.746	kilowatts (kw)
	PRESSURE OR STRESS	
Inches of water	0.2491	kilopascals (kPa)
Pounds/sq. in.	6.895	kilopascals
	ENERGY OR WORK	
BTU	1055.0	joules (J)
Foot - pound	1.3558	joules
Kilowatt-hour	3600000.0	joules (J = one W/s)

CONVERSION TABLE
METRIC TO ENGLISH

WHEN YOU KNOW	MULTIPLY BY: * = Exact		TO FIND
↓	VERY ACCURATE	APPROXIMATE	↓
	LENGTH		
millimetres	0.0393701	0.04	inches
centimetres	0.3937008	0.4	inches
metres	3.280840	3.3	feet
metres	1.093613	1.1	yards
kilometres	0.621371	0.6	miles
	WEIGHT		
grains	0.00228571	0.0023	ounces
grams	0.03527396	0.035	ounces
kilograms	2.204623	2.2	pounds
tonnes	1.1023113	1.1	short tons
	VOLUME		
millilitres		0.2	teaspoons
millilitres	0.06667	0.067	tablespoons
millilitres	0.03381402	0.03	fluid ounces
litres	61.02374	61.024	cubic inches
litres	2.113376	2.1	pints
litres	1.056688	1.06	quarts
litres	0.26417205	0.26	gallons
litres	0.03531467	0.035	cubic feet
cubic metres	61023.74	61023.7	cubic inches
cubic metres	35.31467	35.0	cubic feet
cubic metres	1.3079506	1.3	cubic yards
cubic metres	264.17205	264.0	gallons
	AREA		
square centimetres	0.1550003	0.16	square inches
square centimetres	0.00107639	0.001	square feet
square metres	10.76391	10.8	square feet
square metres	1.195990	1.2	square yards
square kilometres		0.4	square miles
hectares	2.471054	2.5	acres
	TEMPERATURE		
Celsius	*9/5 (then add 32)		Fahrenheit

CONVERSION TABLE
ENGLISH TO METRIC

WHEN YOU KNOW	MULTIPLY BY: * = Exact		TO FIND
	VERY ACCURATE	APPROXIMATE	
	LENGTH		
inches	* 25.4		millimetres
inches	* 2.54		centimetres
feet	* 0.3048		metres
feet	* 30.48		centimetres
yards	* 0.9144	0.9	metres
miles	* 1.609344	1.6	kilometres
	WEIGHT		
grains	15.43236	15.4	grams
ounces	* 28.349523125	28.0	grams
ounces	* 0.028349523125	.028	kilograms
pounds	* 0.45359237	0.45	kilograms
short ton	* 0.90718474	0.9	tonnes
	VOLUME		
teaspoons		5.0	millilitres
tablespoons		15.0	millilitres
fluid ounces	29.57353	30.0	millilitres
cups		0.24	litres
pints	* 0.473176473	0.47	litres
quarts	* 0.946352946	0.95	litres
gallons	* 3.785411784	3.8	litres
cubic inches	* 0.016387064	0.02	litres
cubic feet	* 0.028316846592	0.03	cubic metres
cubic yards	* 0.764554857984	0.76	cubic metres
	AREA		
square inches	* 6.4516	6.5	square centimetres
square feet	* 0.09290304	0.09	square metres
square yards	* 0.83612736	0.8	square metres
square miles		2.6	square kilometres
acres	* 0.40468564224	0.4	hectares
	TEMPERATURE		
Fahrenheit	* 5/9 (after subtracting 32)		Celsius

DIMENSIONAL AND TEMPERATURE CONVERSION CHART

INCHES	DECIMALS	MILLI-METRES	INCHES TO MILLIMETRES		MILLIMETRES TO INCHES		FAHRENHEIT & CENTIGRADE			
			Inches	m.ms.	m.ms.	Inches	°F	°C	°C	°F
1/64	.015625	.3969	.0001	.00254	0.001	.000039	-20	-28.9	-30	-22
1/32	.03125	.7937	.0002	.00508	0.002	.000079	-15	-26.1	-28	-18.4
3/64	.046875	1.1906	.0003	.00762	0.003	.000118	-10	-23.3	-26	-14.8
1/16	.0625	1.5875	.0004	.01016	0.004	.000157	-5	-20.6	-24	-11.2
5/64	.078125	1.9844	.0005	.01270	0.005	.000197	0	-17.8	-22	-7.6
3/32	.09375	2.3812	.0006	.01524	0.006	.000236	1	-17.2	-20	-4
7/64	.109375	2.7781	.0007	.01778	0.007	.000276	2	-16.7	-18	-0.4
1/8	.125	3.1750	.0008	.02032	0.008	.000315	3	-16.1	-16	3.2
9/64	.140625	3.5719	.0009	.02286	0.009	.000354	4	-15.6	-14	6.8
5/32	.15625	3.9687	.001	.0254	0.01	.00039	5	-15.0	-12	10.4
11/64	.171875	4.3656	.002	.0508	0.02	.00079	10	-12.2	-10	14
3/16	.1875	4.7625	.003	.0762	0.03	.00118	15	-9.4	-8	17.6
13/64	.203125	5.1594	.004	.1016	0.04	.00157	20	-6.7	-6	21.2
7/32	.21875	5.5562	.005	.1270	0.05	.00197	25	-3.9	-4	24.8
15/64	.234375	5.9531	.006	.1524	0.06	.00236	30	-1.1	-2	28.4
1/4	.25	6.3500	.007	.1778	0.07	.00276	35	1.7	0	32
17/64	.265625	6.7469	.008	.2032	0.08	.00315	40	4.4	2	35.6
9/32	.28125	7.1437	.009	.2286	0.09	.00354	45	7.2	4	39.2
19/64	.296875	7.5406	.01	.254	0.1	.00394	50	10.0	6	42.8
5/16	.3125	7.9375	.02	.508	0.2	.00787	55	12.8	8	46.4
21/64	.328125	8.3344	.03	.762	0.3	.01181	60	15.6	10	50
11/32	.34375	8.7312	.04	1.016	0.4	.01575	65	18.3	12	53.6
23/64	.359375	9.1281	.05	1.270	0.5	.01969	70	21.1	14	57.2
3/8	.375	9.5250	.06	1.524	0.6	.02362	75	23.9	16	60.8
25/64	.390625	9.9219	.07	1.778	0.7	.02756	80	26.7	18	64.4
13/32	.40625	10.3187	.08	2.032	0.8	.03150	85	29.4	20	68
27/64	.421875	10.7156	.09	2.286	0.9	.03543	90	32.2	22	71.6
7/16	.4375	11.1125	.1	2.54	1	.03937	95	35.0	24	75.2
29/64	.453125	11.5094	.2	5.08	2	.07874	100	37.8	26	78.8
15/32	.46875	11.9062	.3	7.62	3	.11811	105	40.6	28	82.4
31/64	.484375	12.3031	.4	10.16	4	.15748	110	43.3	30	86
1/2	.5	12.7000	.5	12.70	5	.19685	115	46.1	32	89.6
33/64	.515625	13.0969	.6	15.24	6	.23622	120	48.9	34	93.2
17/32	.53125	13.4937	.7	17.78	7	.27559	125	51.7	36	96.8
35/64	.546875	13.8906	.8	20.32	8	.31496	130	54.4	38	100.4
9/16	.5625	14.2875	.9	22.86	9	.35433	135	57.2	40	104
37/64	.578125	14.6844	1	25.4	10	.39370	140	60.0	42	107.6
19/32	.59375	15.0812	2	50.8	11	.43307	145	62.8	44	112.2
39/64	.609375	15.4781	3	76.2	12	.47244	150	65.6	46	114.8
5/8	.625	15.8750	4	101.6	13	.51181	155	68.3	48	118.4
41/64	.640625	16.2719	5	127.0	14	.55118	160	71.1	50	122
21/32	.65625	16.6687	6	152.4	15	.59055	165	73.9	52	125.6
43/64	.671875	17.0656	7	177.8	16	.62992	170	76.7	54	129.2
11/16	.6875	17.4625	8	203.2	17	.66929	175	79.4	56	132.8
45/64	.703125	17.8594	9	228.6	18	.70866	180	82.2	58	136.4
23/32	.71875	18.2562	10	254.0	19	.74803	185	85.0	60	140
47/64	.734375	18.6531	11	279.4	20	.78740	190	87.8	62	143.6
3/4	.75	19.0500	12	304.8	21	.82677	195	90.6	64	147.2
49/64	.765625	19.4469	13	330.2	22	.86614	200	93.3	66	150.8
25/32	.78125	19.8437	14	355.6	23	.90551	205	96.1	68	154.4
51/64	.796875	20.2406	15	381.0	24	.94488	210	98.9	70	158
13/16	.8125	20.6375	16	406.4	25	.98425	212	100.0	75	167
53/64	.828125	21.0344	17	431.8	26	1.02362	215	101.7	80	176
27/32	.84375	21.4312	18	457.2	27	1.06299	220	104.4	85	185
55/64	.859375	21.8281	19	482.6	28	1.10236	225	107.2	90	194
7/8	.875	22.2250	20	508.0	29	1.14173	230	110.0	95	203
57/64	.890625	22.6219	21	533.4	30	1.18110	235	112.8	100	212
29/32	.90625	23.0187	22	558.8	31	1.22047	240	115.6	105	221
59/64	.921875	23.4156	23	584.2	32	1.25984	245	118.3	110	230
15/16	.9375	23.8125	24	609.6	33	1.29921	250	121.1	115	239
61/64	.953125	24.2094	25	635.0	34	1.33858	255	123.9	120	248
31/32	.96875	24.6062	26	660.4	35	1.37795	260	126.6	125	257
63/64	.984375	25.0031	27	690.6	36	1.41732	265	129.4	130	266

CAPACITY CONVERSION U.S. GALLONS TO LITRES

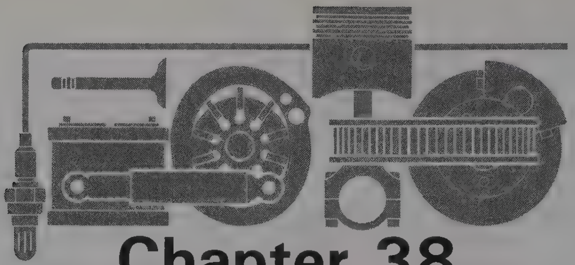
Gallons	0	1	2	3	4	5
	Litres	Litres	Litres	Litres	Litres	Litres
0	00.0000	3.7853	7.5707	11.3560	15.1413	18.9267
10	37.8533	41.6387	45.4240	49.2098	52.9947	56.7800
20	75.7066	79.4920	83.2773	87.0626	90.8480	94.6333
30	113.5600	117.3453	121.1306	124.9160	128.7013	132.4866
40	151.4133	155.1986	158.9840	162.7693	166.5546	170.3400

MILLIMETRE CONVERSION CHART

mm. Ins.	15 = .5905	30 = 1.1811	45 = 1.7716	60 = 2 3622	75 = 2.9527	90 = 3.5433	105 = 4.1338	120 = 4.7244
.25 = .0098	15.25 = .6004	30.25 = 1.1909	45.25 = 1.7815	60.25 = 2.3720	75.25 = 2.9626	90.25 = 3.5531	105.25 = 4.1437	120.25 = 4.7342
.50 = .0197	15.50 = .6102	30.50 = 1.2008	45.50 = 1.7913	60.50 = 2.3819	75.50 = 2.9724	90.50 = 3.5630	105.50 = 4.1535	120.50 = 4.7441
.75 = .0295	15.75 = .6201	30.75 = 1.2106	45.75 = 1.8012	60.75 = 2.3917	75.75 = 2.9823	90.75 = 3.5728	105.75 = 4.1634	120.75 = 4.7539
1 = .0394	16 = .6299	31 = 1.2205	46 = 1.8110	61 = 2.4016	76 = 2.9921	91 = 3.5827	106 = 4.1732	121 = 4.7638
1.25 = .0492	16.25 = .6398	31.25 = 1.2303	46.25 = 1.8209	61.25 = 2.4114	76.25 = 3.0020	91.25 = 3.5925	106.25 = 4.1831	121.25 = 4.7736
1.50 = .0591	16.50 = .6496	31.50 = 1.2402	46.50 = 1.8307	61.50 = 2.4213	76.50 = 3.0118	91.50 = 3.6024	106.50 = 4.1929	121.50 = 4.7885
1.75 = .0689	16.75 = .6594	31.75 = 1.2500	46.75 = 1.8405	61.75 = 2.4311	76.75 = 3.0216	91.75 = 3.6122	106.75 = 4.2027	121.75 = 4.7933
2 = .0787	17 = .6693	32 = 1.2598	47 = 1.8504	62 = 2.4409	77 = 3.0315	92 = 3.6220	107 = 4.2126	122 = 4.8031
2.25 = .0886	17.25 = .6791	32.25 = 1.2697	47.25 = 1.8602	62.25 = 2.4508	77.25 = 3.0413	92.25 = 3.6319	107.25 = 4.2224	122.25 = 4.8130
2.50 = .0984	17.50 = .6890	32.50 = 1.2795	47.50 = 1.8701	62.50 = 2.4606	77.50 = 3.0512	92.50 = 3.6417	107.50 = 4.2323	122.50 = 4.8228
2.75 = .1083	17.75 = .6988	32.75 = 1.2894	47.75 = 1.8799	62.75 = 2.4705	77.75 = 3.0610	92.75 = 3.6516	107.75 = 4.2421	122.75 = 4.8327
3 = .1181	18 = .7087	33 = 1.2992	48 = 1.8898	63 = 2.4803	78 = 3.0709	93 = 3.6614	108 = 4.2520	123 = 4.8425
3.25 = .1280	18.25 = .7185	33.25 = 1.3091	48.25 = 1.8996	63.25 = 2.4901	78.25 = 3.0807	93.25 = 3.6713	108.25 = 4.2618	123.25 = 4.8524
3.50 = .1378	18.50 = .7283	33.50 = 1.3189	48.50 = 1.9094	63.50 = 2.5000	78.50 = 3.0905	93.50 = 3.6811	108.50 = 4.2716	123.50 = 4.8622
3.75 = .1476	18.75 = .7382	33.75 = 1.3287	48.75 = 1.9193	63.75 = 2.5098	78.75 = 3.1004	93.75 = 3.6909	108.75 = 4.2815	123.75 = 4.8720
4 = .1575	19 = .7480	34 = 1.3386	49 = 1.9291	64 = 2.5197	79 = 3.1102	94 = 3.7008	109 = 4.2913	124 = 4.8819
4.25 = .1673	19.25 = .7579	34.25 = 1.3484	49.25 = 1.9390	64.25 = 2.5295	79.25 = 3.1201	94.25 = 3.7106	109.25 = 4.3012	124.25 = 4.8917
4.50 = .1772	19.50 = .7677	34.50 = 1.3583	49.50 = 1.9488	64.50 = 2.5394	79.50 = 3.1299	94.50 = 3.7205	109.50 = 4.3110	124.50 = 4.9016
4.75 = .1870	19.75 = .7776	34.75 = 1.3681	49.75 = 1.9587	64.75 = 2.5492	79.75 = 3.1398	94.75 = 3.7303	109.75 = 4.3209	124.75 = 4.9114
5 = .1968	20 = .7874	35 = 1.3779	50 = 1.9685	65 = 2.5590	80 = 3.1496	95 = 3.7401	110 = 4.3307	125 = 4.9212
5.25 = .2067	20.25 = .7972	35.25 = 1.3878	50.25 = 1.9783	65.25 = 2.5689	80.25 = 3.1594	95.25 = 3.7500	110.25 = 4.3405	125.25 = 4.9311
5.50 = .2165	20.50 = .8071	35.50 = 1.3976	50.50 = 1.9882	65.50 = 2.5787	80.50 = 3.1693	95.50 = 3.7598	110.50 = 4.3504	125.50 = 4.9409
5.75 = .2264	20.75 = .8169	35.75 = 1.4075	50.75 = 1.9980	65.75 = 2.5886	80.75 = 3.1791	95.75 = 3.7697	110.75 = 4.3602	125.75 = 4.9508
6 = .2362	21 = .8268	36 = 1.4173	51 = 2.0079	66 = 2.5984	81 = 3.1890	96 = 3.7795	111 = 4.3701	126 = 4.9606
6.25 = .2461	21.25 = .8366	36.25 = 1.4272	51.25 = 2.0177	66.25 = 2.6083	81.25 = 3.1988	96.25 = 3.7894	111.25 = 4.3799	126.25 = 4.9705
6.50 = .2559	21.50 = .8465	36.50 = 1.4370	51.50 = 2.0276	66.50 = 2.6181	81.50 = 3.2087	96.50 = 3.7992	111.50 = 4.3898	126.50 = 4.9803
6.75 = .2657	21.75 = .8563	36.75 = 1.4468	51.75 = 2.0374	66.75 = 2.6279	81.75 = 3.2185	96.75 = 3.8090	111.75 = 4.3996	126.75 = 4.9901
7 = .2756	22 = .8661	37 = 1.4567	52 = 2.0472	67 = 2.6378	82 = 3.2283	97 = 3.8189	112 = 4.4094	127 = 5.0000
7.25 = .2854	22.25 = .8760	37.25 = 1 4665	52.25 = 2.0571	67.25 = 2.6476	82.25 = 3.2382	97.25 = 3.8287	112.25 = 4.4193	
7.50 = .2953	22.50 = .8858	37.50 = 1.4764	52.50 = 2.0669	67.50 = 2.6575	82.50 = 3.2480	97.50 = 3.8386	112.50 = 4.4291	
7.75 = .3051	22.75 = .8957	37.75 = 1.4862	52.75 = 2.0768	67.75 = 2.6673	82.75 = 3.2579	97.75 = 3.8484	112.75 = 4.4390	
8 = .3150	23 = .9055	38 = 1.4961	53 = 2.0866	68 = 2.6772	83 = 3.2677	98 = 3.8583	113 = 4.4488	
8.25 = .3248	23.25 = .9153	38.25 = 1.5059	53.25 = 2.0965	68.25 = 2.6870	83.25 = 3.2776	98.25 = 3.8681	113.25 = 4.4587	
8.50 = .3346	23.50 = 9252	38.50 = 1.5157	53.50 = 2.1063	68.50 = 2.6968	83.50 = 3.2874	98.50 = 3.8779	113.50 = 4.4685	
8.75 = .3445	23.75 = .9350	38.75 = 1.5256	53.75 = 2.1161	68.75 = 2.7067	83.75 = 3.2972	98.75 = 3.8878	113.75 = 4.4783	
9 = .3543	24 = .9449	39 = 1.5354	54 = 2.1260	69 = 2.7165	84 = 3.3071	99 = 3.8976	114 = 4.4882	
9.25 = .3642	24.25 = .9547	39.25 = 1.5453	54.25 = 2.1358	69.25 = 2.7264	84.25 = 3.3169	99.25 = 3.9075	114.25 = 4.4980	
9.50 = .3740	24.50 = .9646	39.50 = 1.5551	54.50 = 2.1457	69.50 = 2.7362	84.50 = 3.3268	99.50 = 3.9173	114.50 = 4.5079	
9.75 = .3839	24.75 = .9744	39.75 = 1.5650	54.75 = 2.1555	69.75 = 2.7461	84.75 = 3.3366	99.75 = 3.9272	114.75 = 4.5177	
10 = .3937	25 = .9842	40 = 1.5748	55 = 2.1653	70 = 2.7559	85 = 3.3464	100 = 3.9370	115 = 4.5275	
10.25 = .4035	25.25 = .9941	40.25 = 1.5846	55.25 = 2.1752	70.25 = 2.7657	85.25 = 3.3563	100.25 = 3.9468	115.25 = 4.5374	
10.50 = .4134	25.50 = 1.0039	40.50 = 1.5945	55.50 = 2.1850	70.50 = 2.7756	85.50 = 3.3661	100.50 = 3.9567	115.50 = 4.5472	
10.75 = .4232	25.75 = 1.0138	40.75 = 1.6043	55.75 = 2.1949	70.75 = 2.7854	85.75 = 3.3760	100.75 = 3.9665	115.75 = 4.5571	
11 = .4331	26 = 1.0236	41 = 1.6142	56 = 2.2047	71 = 2.7953	86 = 3.3858	101 = 3.9764	116 = 4.5669	
11.25 = .4429	26.25 = 1.0335	41.25 = 1.6240	56.25 = 2.2146	71.25 = 2.8051	86.25 = 3.3957	101.25 = 3.9862	116.25 = 4.5768	
11.50 = .4528	26.50 = 1.0433	41.50 = 1.6339	56.50 = 2.2244	71.50 = 2.8150	86.50 = 3.4055	101.50 = 3.9961	116.50 = 4.5866	
11.75 = .4626	26.75 = 1.0531	41.75 = 1.6437	56.75 = 2.2342	71.75 = 2.8248	86.75 = 3.4153	101.75 = 4.0059	116.75 = 4.5964	
12 = .4724	27 = 1.0630	42 = 1.6535	57 = 2.2441	72 = 2.8346	87 = 3.4252	102 = 4.0157	117 = 4.6063	
12.25 = .4823	27.25 = 1.0728	42.25 = 1.6634	57.25 = 2.2539	72.25 = 2.8445	87.25 = 3.4350	102.25 = 4.0256	117.25 = 4.6161	
12.50 = .4921	27.50 = 1.0827	42.50 = 1.6732	57.50 = 2.2638	72.50 = 2.8543	87.50 = 3.4449	102.50 = 4.0354	117.50 = 4.6260	
12.75 = .5020	27.75 = 1.0925	42.75 = 1.6831	57.75 = 2.2736	72.75 = 2.8642	87.75 = 3.4547	102.75 = 4.0453	117.75 = 4.6358	
13 = .5118	28 = 1.1024	43 = 1.6929	58 = 2.2835	73 = 2.8740	88 = 3.4646	103 = 4.0551	118 = 4.6457	
13.25 = .5217	28.25 = 1.1122	43.25 = 1.7028	58.25 = 2.2933	73.25 = 2.8839	88.25 = 3.4744	103.25 = 4.0650	118.25 = 4.6555	
13.50 = .5315	28.50 = 1.1220	43.50 = 1.7126	58.50 = 2.3031	73.50 = 2.8937	88.50 = 3.4842	103.50 = 4.0748	118.50 = 4.6653	
13.75 = .5413	28.75 = 1.1319	43.75 = 1.7224	58.75 = 2.3130	73.75 = 2.9035	88.75 = 3.4941	103.75 = 4.0846	118.75 = 4.6752	
14 = .5512	29 = 1.1417	44 = 1.7323	59 = 2.3228	74 = 2.9134	89 = 3.5039	104 = 4.0945	119 = 4.6850	
14.25 = .5610	29.25 = 1.1516	44.25 = 1.7421	59.25 = 2.3327	74.25 = 2.9232	89.25 = 3.5138	104.25 = 4.1043	119.25 = 4.6949	
14.50 = .5709	29.50 = 1.1614	44.50 = 1.7520	59.50 = 2.3425	74.50 = 2.9331	89.50 = 3.5236	104.50 = 4.1142	119.50 = 4.7047	
14.75 = .5807	29.75 = 1.1713	44.75 = 1.7618	59.75 = 2.3524	74.74 = 2.9429	89.75 = 3.5335	104.75 = 4.1240	119.75 = 4.7146	

METRIC — INCH EQUIVALENTS

INCHES		MILLIMETRES
FRACTIONS	DECIMALS	
	.00394	.1
	.00787	.2
	.01181	.3
1/64	.015625	.3969
	.01575	.4
	.01969	.5
	.02362	.6
	.02756	.7
1/32	.03125	.7938
	.0315	.8
	.03543	.9
	.03937	1.00
3/64	.046875	1.1906
1/16	.0625	1.5875
5/64	.078125	1.9844
	.07874	2.00
3/32	.09375	2.3813
7/64	.109375	2.7781
	.11811	3.00
1/8	.125	3.175
9/64	.140625	3.5719
5/32	.15625	3.9688
	.15748	4.00
11/64	.171875	4.3656
3/16	.1875	4.7625
	.19685	5.00
13/64	.203125	5.1594
7/32	.21875	5.5563
15/64	.234375	5.9531
	.23622	6.00
1/4	.2500	6.35
17/64	.265625	6.7469
	.27559	7.00
9/32	.28125	7.1438
19/64	.296875	7.5406
5/16	.3125	7.9375
	.31496	8.00
21/64	.328125	8.3344
11/32	.34375	8.7313
	.35433	9.00
23/64	.359375	9.1281
3/8	.375	9.525
25/64	.390625	9.9219
	.3937	10.00
13/32	.40625	10.3188
27/64	.421875	10.7156
	.43307	11.00
7/16	.4375	11.1125
29/64	.453125	11.5094
15/32	.46875	11.9063
	.47244	12.00
31/64	.484375	12.3031
1/2	.5000	12.70
	.51181	13.00
33/64	.515625	13.0969
17/32	.53125	13.4938
35/64	.546875	13.8907
	.55118	14.00
9/16	.5625	14.2875
37/64	.578125	14.6844
	.59055	15.00
19/32	.59375	15.0813
39/64	.609375	15.4782
5/8	.625	15.875
	.62992	16.00
41/64	.640625	16.2719
21/32	.65625	16.6688
	.66929	17.00
43/64	.671875	17.0657
11/16	.6875	17.4625
45/64	.703125	17.8594
	.70866	18.00
23/32	.71875	18.2563
47/64	.734375	18.6532
	.74803	19.00
3/4	.7500	19.05
49/64	.765625	19.4469
25/32	.78125	19.8438
	.7874	20.00
51/64	.796875	20.2407
13/16	.8125	20.6375
	.82677	21.00
53/64	.828125	21.0344
27/32	.84375	21.4313
55/64	.859375	21.8282
	.86614	22.00
7/8	.875	22.225
57/64	.890625	22.6219
	.90551	23.00
29/32	.90625	23.0188
59/64	.921875	23.4157
15/16	.9375	23.8125
	.94488	24.00
61/64	.953125	24.2094
31/32	.96875	24.6063
	.98425	25.00
63/64	.984375	25.0032
1	1.0000	25.4001



Chapter 38

DICTIONARY OF AUTOMOTIVE TERMS

A

AAA: American Automobile Association.

ABDC: After Bottom Dead Center.

ABSOLUTE ZERO: A state in which no heat is present. Believed to be −459.7°F or −273.16°C.

AC: Alternating current.

ACCELERATOR: Floor pedal used to control, through linkage, throttle valve in carburetor.

ACCELERATOR PUMP: Small pump, located in carburetor, that sprays additional gasoline into air stream during acceleration.

ACCUMULATOR (Air conditioning): Receiver-dehydrator combination.

ACCUMULATOR PISTON (Automatic transmission): Unit designed to assist the servo to apply brake band quickly, yet smoothly.

ACETONE: Very flammable, volatile solvent. Mixes with water.

ACETYLENE: Gas commonly used in welding or cutting operations.

ACID CORE (Solder): Wire solder with a central core containing an acid flux.

ACKERMAN PRINCIPLE: Bending outer ends of steering arms slightly inward so that when car is making a turn, inside wheel will turn more sharply than outer wheel. This principle produces toe-out on turns.

ACTUATOR: Device that converts electrical signals into physical actions. Most actuators are classified as motors, solenoids, or relays.

ADDITIVE: Solution, powder, etc., added to gasoline, oil, grease, etc., in an endeavor to improve characteristics of original product.

ADJUSTABLE PILOT (Valve grinding): An expandable device used to position and guide either cutter or stone mandrels (sleeve) for valve grinding.

ADVANCE (Ignition timing): To set ignition timing so a spark occurs earlier or more degrees before TDC.

AEA: Automotive Electric Association.

AERA: Automotive Engine Rebuilders Association.

AERATION: Process of mixing air into a solution such as engine coolant.

AFBMA: Antifriction Bearing Manufacturers Association.

AGITATION (Cleaning): Shaking or vibration applied to a cleaning solution to assist cleaning process.

AHRA: American Hot Rod Association.

AIR: Air Injection Reactor system of reducing objectionable exhaust emissions.

AIR BAG SYSTEM: Restraint system that uses an inflatable bag to protect occupants during a severe frontal collision.

AIR BLEED: An orifice or small passageway designed to allow a specific amount of air to enter a moving column of liquid (such as fuel).

AIR CLEANER: Device used to remove dust, abrasive, etc., from air being drawn into an engine, compressor, power brake, etc.

AIR CONDITIONING: Controlling the temperature, movement, cleanliness, and humidity of air.

AIR CONDITIONING SPECIALIST: Person highly trained and knowledgeable in the field of automotive air conditioning.

AIR COOLED: An object cooled by passing a stream of air over its surface.

AIR DAM: A device placed beneath front bumper to reduce amount of air turbulence and drag under car.

AIR DRILL: Drill operated by air pressure.

AIR FILTER: A device through which air is drawn to remove dust, dirt, etc.

AIRFLOW SENSOR: Device to measure volume and speed of air moving into intake manifold. Sensor controls rate of fuel flow.

AIR FOIL: Device, similar to a stubby wing, mounted onto a racing car or dragster to provide high speed stability. The air foil is mounted in a horizontal position.

AIR-FUEL RATIO: Ratio (by weight or by volume) between air and gasoline that makes up engine fuel mixture.

AIR GAP (Regulator): Distance between contact armature and iron core that when magnetized, draws armature down.

AIR GAP (Spark plugs): Distance between center and side electrodes.

AIR HORN (Carburetor): Top portion of air passageway through carburetor.

AIR HORN (Accessory): Warning horn operated by compressed air.

AIR INJECTION REACTION: An emission control system used to lower levels of carbon monoxide and hydrocarbon emissions. Accomplished by injecting a stream of air into exhaust stream near exhaust valve.

AIR OPERATED: Press, lift, etc., operated by compressed air as opposed to a fluid.

AIR POLLUTION: Contamination of earth's atmosphere by various natural and manufactured pollutants such as smoke, gases, dust, etc.

AIR PRESSURE CHECK (Automatic transmission): Using compressed air to check clutch and band operation.

AIR SPRING: Container and plunger separated by air under pressure. When container and plunger attempt to squeeze together, air compresses and produces a spring effect. Air spring has been used on some suspension systems.

ALIGN: To bring various parts of unit into correct positions in respect to each other or to a predetermined location.

ALIGNING BAR (Crankshaft): A precision tool (bar) used to check engine main bearing alignment.

ALIGNING PUNCH: Punch with a long, gradual taper that may be passed through holes in two objects, thus aligning the holes for insertion of fasteners, etc.

ALLOY: Mixture of two or more materials.

ALNICO MAGNET: Magnet using (Al) aluminum, (Ni) nickel, and (Co) cobalt in its construction.

ALPHA NUMERIC (Tire): Tire size designation using letters to indicate load carrying capacity. Example: GR 78-15. The letter G = load/size relationship. R = radial construction. 78 = height to width ratio. 15 = rim diameter in inches.

ALTERNATOR: Device similar to generator but produces AC current. The AC is rectified before reaching car's electrical system.

ALTERNATING CURRENT (AC): Electric current that first flows one way in circuit and then other. Type used in homes.

ALTITUDE COMPENSATION: Altering the adjustment, tension, position, etc., of some unit such as a carburetor, vacuum modulator, etc., so that unit operation will be in conformance to that required at any specific elevation.

ALUMINUM OXIDE (Abrasive): An abrasive (sanding) paper coated with particles of aluminum oxide.

ALUMINUM OXIDE BEADS: Beads, made of aluminum oxide used in construction of catalytic converters.

AMA: Automobile Manufacturers Association.

AMALGAMATE: A mixture of two or more materials or compounds — such as solder, which is made up basically of tin and lead.

AMBIENT TEMPERATURE: Temperature of air surrounding an object.

AMC: American Motors Corporation.

AMMETER: Instrument used to measure rate of current flow in amperes.

AMPERE: Unit of measurement used in expressing rate of current flow in a circuit.

AMPERE HOUR CAPACITY: Measurement of storage battery ability to deliver specified current over specified length of time.

ANEROID: A device, such as a barometer bellows, that neither contains nor uses a liquid.

ANEROID BAROMETER: A device to measure atmospheric pressure. It utilizes an aneroid capsule (bellows) that expands and contracts with differences in pressure.

ANGLE OF APPROACH: The steepest angle that a vehicle can drive up on from a level surface without dragging the front end of vehicle.

ANGLE OF DEPARTURE: The steepest angle that a vehicle can descend and drive off onto a level surface without dragging rear of vehicle.

ANGULAR CONTACT (Bearing): An antifriction bearing, such as a ball bearing, designed to carry both radial and thrust loads.

ANNEAL: To remove hardness from metal. Heat steel to a red color, then allow it to cool slowly. Unlike steel, copper is annealed by heating, and then plunging it immediately into cold water.

ANNEALED STAINLESS STEEL: Stainless steel that has been heat treated to remove stress and to soften.

ANNULAR GROOVE: A groove, such as used for bearing oil distribution, snap ring installation, etc., that runs completely around a bearing, shaft, etc.

ANNULUS GEAR: A ring shaped gear such as the internal tooth ring (annulus) gear used in some overdrive units.

ANODE: In an electric circuit—the positive pole.

ANTIBACKFIRE VALVE: Valve used in air injection reaction (exhaust emission control) system to prevent backfiring during period immediately following sudden deceleration.

ANTIFREEZE: Chemical added to cooling system to prevent coolant from freezing in cold weather.

ANTIFRICTION BEARING: Bearing containing rollers or balls plus an inner and outer race. Bearing is designed to roll, thus minimizing friction.

ANTIKNOCK (Fuel): Indicates various substances, such as tetraethyl lead, that can be added to gasoline to improve its resistance to knocking (spark knock, preignition, or detonation).

ANTILASH PLATE: A plate designed to maintain constant and intimate contact between two gears. This removes "play" or "backlash".

ANTI-LOCK BRAKES: Computerized brake system that prevents wheel lock-up by pulsating fluid pressure to affected wheel(s).

ANTIPERCOLATOR: Device for venting vapors from main discharge tube, or well, of a carburetor.

ANTISEIZE COMPOUND: A compound designed to prevent galling, sticking, or seizing of fastener threads.

ANTISTALL DASHPOT (Carburetor): A diaphragm operated unit designed to retard final closing of throttle valve to prevent stalling.

API: American Petroleum Insititute.

APPLY SERVO (Transmission): The hydraulically operated pistons used to apply bands in an automatic transmission.

APRA: Automotive Parts Rebuilders Association.

APPRENTICE PROGRAM: Educational program designed to teach a trade through on-the-job training and study.

ARBOR PRESS: A stout press, often hand operated, used to insert or remove bearings, bushings, collars, etc.

ARC OR ELECTRIC WELDING: Welding by using electric currrent to melt both metal to be welded and welding rod or electrode that is being added.

ARCING: Electricity leaping the gap between two electrodes.

ARMATURE (Relay, regulator, horn, etc.): The movable part of the unit.

ARMATURE (Starter or generator): The portion that revolves between the pole shoes, made up of wire windings on an iron core.

ASBESTOS: Heat resistant and nonburning fibrous mineral widely used for brake shoes, clutch linings, etc. Do not inhale asbestos fibers or dust. Believed to cause cancer.

ASBESTOS WICK SEAL: Bearing oil seal constructed of woven asbestos fibers.

ASLE: American Society of Lubrication Engineers.

ASME: American Society of Mechanical Engineers.

ASSE: American Society of Safety Engineers.

ASPECT RATIO (Tire): Ratio between height and width of a tire.

ASTM: American Society of Testing Materials.

ASYMMETRIC TIRE TREAD: Tire tread with a non-symmetrical (uneven) pattern. Designed to reduce tire vibration and noise.

ATA: American Trucking Association.

ATDC: After Top Dead Center.

ATMOSPHERE: Layer of gases (referred to as air) surrounding earth.

ATMOSPHERIC PRESSURE: Pressure exerted by atmosphere on all things exposed to it. Around 14.7 pounds per square inch or 101 kPa at sea level.

ATOM: Tiny particle of matter made up of electrons, protons, and neutrons. Atoms or combinations of atoms make up molecules. Electrons orbit around center or nucleus made up of protons and neutrons.

ATOMIZE: To break a liquid into tiny droplets.

AUTOMATIC CHOKE: A carburetor choke device that automatically positions itself in accordance with carburetor needs.

AUTOMATIC LEVELING CONTROL: Pressure system which maintains proper body height with changes in load.

AUTOMATIC TRANSMISSION: A transmission that shifts itself. Shift range and points are determined by road speed, quadrant position, engine loading, etc.

AUTOMATIC TRANSMISSION FLUID (ATF): Special lubricating fluid designed for use in automatic transmissions.

AWG: American Wire Gauge. United States standard for measurement of nonferrous wires, sheet material, and rods.

AWL (Tire): Sharp pointed steel tool used to probe cuts, nail holes, etc., in tires.

AXIAL: Direction parallel to shaft or bearing hole.

AXIAL COMPRESSOR: An air conditioning compressor in which a series of pistons are moved in an axial direction by a swash plate.

AXIS: The line about which a revolving object rotates.

AXLE (Full-floating): Axle used to drive rear wheels. It does not hold them on nor support them.

AXLE (Semi or one-quarter floating): Axle used to drive wheels, hold them on, and support them.

AXLE (Three-quarter floating): Axle used to drive rear wheels as well as hold them on. It does not support them.

AXLE END GEARS: Two gears, one per axle, that are splined to the inner ends of drive axles. They mesh with and are driven by "spider" gears.

AXLE END PLAY: Axle shaft "play" or movement in an endwise direction.

AXLE HOUSING: Enclosure for axles and differential. It is partially filled with differential fluid (oil).

AXLE RATIO: Relationship or ratio between the number of times the propeller shaft must revolve to turn the axle drive shafts one turn.

AXLE RETAINER: Device such as a nut, collar, C-lock, etc., designed to secure axle in place.

AXLE SIDE GEAR: Gear on drive axle inner end. It mates with differential pinion gears. In turn, through the pinion shaft, it connects axles to differential case.

B

BABBITTED BEARING: A bearing in which bearing material, in this case babbit, is bonded directly to bearing housing.

BACKFIRE (Intake system): Burning of fuel mixture in intake manifold. May be caused by faulty timing, crossed plug wires, leaky intake valve, etc.

BACKFIRE (Exhaust system): Passage of unburned fuel mixture into exhaust system where it is ignited and causes an explosion (backfire).

BACKHAND WELDING: A method of oxy-acetylene welding in which torch tip faces into puddle, AWAY from direction of welding.

BACKLASH: Amount of "play" between two parts. In case of gears, it refers to how much one gear can be moved back and forth without moving gear into which it is meshed.

BACK PRESSURE: Resistance to flow of exhaust gases through exhaust system.

BACK PRESSURE TRANSDUCER VALVE (BPV): A valve, sensitive to engine exhaust system back pressure, that adjusts or modulates action of EGR (Exhaust Gas Recirculation) valve.

BACKUP LIGHTS: White lights attached to the rear of a vehicle. Lights are turned on whenever transmission is placed in reverse. Provides illumination for backing at night.

BAFFLE: Obstruction used to slow down or divert the flow of gases, liquids, sound, etc.

BALANCE (Tire): See Static Balance and Dynamic Balance.

BALANCE POINT (Lifting): That point or location at which an object may be lifted while retaining proper balance (equal weight on both sides of lift point).

BALANCE WEIGHT: A weight that is added to a rotating shaft, wheel, etc., so as to bring object into balance to prevent vibration.

BALK RING: Ring attached to balk gear hub in overdrive unit. It lets gear rotate while ring is stationary.

BALL AND TRUNNION: Type of universal joint using needle bearing mounted balls which swivel inside sockets.

BALL BEARING (Antifriction): Bearing consisting of an inner and outer hardened steel race separated by a series of hardened steel balls.

BALL JOINT: Flexible joint utilizing ball and socket type of construction. Used in steering linkage setups, steering knuckle pivot supports, etc.

BALL JOINT ROCKER ARMS: Rocker arms that instead of being mounted on shaft, are mounted upon ball-shaped device on end of stud.

BALL JOINT STEERING KNUCKLE: Steering knuckle that pivots on ball joints instead of on a kingpin.

BALL NUT (Steering gear): That portion of a steering gear riding on the worm shaft (on a series of steel balls) and meshed with pitman shaft sector gear.

BALL PEEN HAMMER: A steel hammer with round peen head on one end. Useful for general striking and for peening pins, rivets, etc.

BALL RACE: That portion of a ball bearing (inner and outer) that contains and bears against bearing balls.

BALL STUD (Valve train): The stud upon which rocker arm pivot ball is affixed.

BALLAST RESISTOR: Resistor constructed of special type wire, properties of which tend to increase or decrease voltage in direct proportion to heat of wire.

BAROMETRIC PRESSURE: Atmospheric pressure as determined by a barometer.

BAROMETRIC PRESSURE SENSITIVE BELLOWS: An evacuated (air removed) bellows that expands or contracts with changes in atmospheric pressure.

BARREL WEAR (Brakes): A brake drum wear pattern in which wear is greater in center of shoe contact area.

BARRIER PLATE (Friction bearing): A very thin plating between copper layer and tin overplate on a precision insert bearing. It prevents tin in overplate from entering copper.

BASE CIRCLE: As applied to camshaft—lowest spot on cam. Area of cam directly opposite lobe.

BASE METAL: Metal underneath a coating or plate. Can refer to metal of parts being welded as opposed to filler metal being added.

BASTARD FILE: A file in which cutting edges are somewhat coarser than those employed by a second cut file.

BATTERY: Electrochemical device for producing electricity.

BATTERY CAPACITY: Rating of current output of battery. Determined by plate size, number of plates, and amount of acid in electrolyte.

BATTERY CHARGING: Process of renewing battery by passing electric current through battery in reverse direction.

BATTERY – MAINTENANCE-FREE: A battery so designed as to not need any additional water during its normal service life.

BATTERY RATING: Standardized measurement of battery's ability to deliver electrical energy under specified conditions.

BATTERY RESERVE CAPACITY: Measurement (in minutes) of battery's ability to supply electrical system energy in event generating system is inoperative.

BATTERY RESERVE CAPACITY RATING: The measure of number of minutes a full charged battery at 80°F (26.7°C) can be discharged at 25 amperes and still maintain a minimum voltage of 1.75 volts per cell.

BATTERY SHEDDING: Grids losing active materials that fall off and settle in bottom of battery case.

BATTERY STATE OF CHARGE: Electrical energy available from a given battery in relation to that which would be normally available if battery were fully charged.

BATTERY VOLTAGE: Determined by the number of cells. Each cell has 2.1V. Three cells will produce a 6V battery and six cells a 12V battery.

BBDC: Before Bottom Dead Center.

BCI: Battery Council International.

BDC: Bottom Dead Center.

BEAD (Tire): Steel wire reinforced portion of tire that engages the wheel rim.

BEAD EXPANDER: A device used to expand tire beads out against rim flange to permit inflation of tubeless tire.

BEAD WIRE (Tire): Steel wire used in tire bead area to prevent bead expansion.

BEARING: Area of unit in which contacting surface of a revolving part rests.

BEARING AXIS: A line through center of a bearing, parallel to length of shaft upon which bearing operates.

BEARING BORE: Center opening in a bearing inner cone or ring. Bore diameter determines shaft, spindle, etc., size applicable to a given bearing.

BEARING CAP: Removable portion of a split (two piece) friction bearing. May contain either an insert or integral bearing surface.

BEARING CAP CROSS BOLT: A strengthening bolt passed through engine crankcase and main bearing cap. When secured, adds rigidity to main bearing cap.

BEARING CLEARANCE: Amount of space left between shaft and bearing surface. This space is for lubricating oil to enter.

BEARING CONE CREEP: Slow rotational movement of the antifriction bearing inner cone or ring around shaft, spindle, etc.

BEARING CONTACT AREA: That area contacted by sliding or rolling elements of a bearing.

BEARING CRUSH: In a precision insert bearing, having bearing ends protrude a very small distance above bearing parting surface. When cap is drawn up, bearing halves are "crushed" into tight contact with bore.

BEARING JOURNAL: That portion of a shaft engaging a friction bearing surface.

BEARING OVEN: A special oven designed to heat and expand antifriction bearing inner cone to aid installation.

BEARING PACKER: A device used to inject grease into an antifriction bearing.

BEARING PRELOAD: Placing a bearing, by means of adjustment, under an initial load. This helps prevent bearing and part misalignment when unit is subjected to normal load stresses.

BEARING SPREAD: In a precision insert bearing, having bearing parting surface diameter slightly larger (positive spread) than bore diameter. This allows bearing to "snap into place" and holds halves in place during assembly.

BELLEVILLE CLUTCH: A traction differential clutch disc and plate assembly constructed so as to impart friction producing pressure when assembled.

BELL HOUSING (Clutch housing): Metal covering around flywheel and clutch, or torque converter assembly.

BELTED BIAS: Tire plies crisscrossed; belts beneath tread area.

BELT SLACK: A measured amount of belt "looseness" or deflection.

BELT TENSION: Amount of contact pressure produced between pulley and belt when belt is tightened. Determined by measuring belt deflection or slack.

BENCH BLEEDING (Master cylinder): Removing air from brake master cylinder before installing new or rebuilt unit on the vehicle.

BENCH GRINDER: Abrasive wheel bolted to a work bench.

BENCH VISE: A vise bolted to a work bench.

BENDING SPRING (Tubing): A special spring that is placed over a section of tubing to permit bending without kinking.

BENDIX TYPE STARTER DRIVE: A self-engaging starter drive gear. Gear moves into engagement when starter starts spinning and automatically disengages when starter stops.

BEVEL EDGE RULE: A rigid steel rule with one or both edges beveled to permit more precise edge viewing and placement.

BEVEL GEAR: Gear in which teeth are cut in a cone shape, as found in axle end gears.

BEVEL SPUR GEAR: Gear in which teeth are cut in a cone shape. Teeth are aligned with cone centerline, as found in some differential gears.

BEZEL: Crimped edge of metal that secures glass face to an instrument.

BHP: Brake horsepower. Measurement of actual power produced by engine.

BIAS-BELTED TIRE: A tire in which sidewall plies are cross-biased at an angle to tire centerline and tread area belts are of radial design. A cross between bias and radial design.

BIAS PLY: Tire plies crisscross; belts not used under tread area.

BIAS TIRE: A tire in which body cord plies are arranged in a cross-biased pattern at an angle to tire centerline.

BLACK LIGHT: Instrument used in detecting leaks, cracks, etc. Emits invisible (ultraviolet) light that when directed on fluorescent materials, causes them to glow.

BLEEDER SCREW: A screw, that when loosened, opens a small hole to permit escape of air trapped in a wheel cylinder, brake cylinder, etc.

BLEEDING: Removing air, pressure, fluid, etc., from a closed system, as in air conditioning.

BLEEDING THE BRAKES: Refers to removal of air from hydraulic system. Bleeder screws are loosened at each wheel cylinder, (one at a time) and brake fluid is forced from master cylinder through lines until all air is expelled.

BLOCK: Part of engine containing cylinders.

BLOCK DISTORTION: Twisting, bending,

etc., of the engine block. Can be caused from overheating, improper fastener torque, internal stress, etc. Can cause cylinder bore, crank bearing bore, etc., distortion, and misalignment.

BLOCK GUIDE PIN: Smooth headed pins that are inserted into cylinder block to provide proper block-to-gasket and cylinder head alignment.

BLOW-BY: Refers to escape of exhaust gases past piston rings.

BLOWER: Supercharger.

BLOWHOLES: Voids in weld metal caused by improper welding technique, settings, filler rod, etc.

BLOWTORCH: A small torch often incorporating an integral fuel tank that is pressurized, via a hand pump, to force fuel under pressure to the torch tip. Useful for heating large soldering coppers, soldering pipes, melting lead, etc.

BLUEPRINTING (Engine): Dismantling engine and reassembling it to EXACT specifications.

BMEP: Brake Mean Effective Pressure.

BODY PUTTY: Material designed to smooth on dented body areas. Upon hardening, putty is dressed down and area painted.

BOILING POINT: Exact temperature at which a liquid begins to boil.

BOLT LENGTH: A measurement taken from end of bolt to underside of bolt head.

BOLT-ON ECCENTRIC: An eccentric (cam shaped) device bolted to camshaft, etc. Converts rotary motion into reciprocating motion to operate fuel pump, vacuum pump, etc.

BONDED BRAKE LINING: Brake lining that is attached to brake shoe by adhesive.

BOOSTER: Device incorporated in car system (such as brakes and steering), to increase pressure output or decrease amount of effort required to operate or both.

BOOSTER BATTERY: An extra battery, connected in parallel to regular vehicle battery. Used as an emergency measure to provide additional cranking capacity when regular battery is damaged, discharged, or of insufficient size.

BOOT: British term for trunk.

BORE: May refer to cylinder itself or to diameter of the cylinder.

BORE ALIGNMENT: An indication of how well true centerline of each one of a series of bores (such as camshaft bearing bores) align with a common centerline through them all. A misaligned bore can be either off-center, out-of-round, or tipped.

BORE DIAMETER: Diameter of cylinders.

BORE FACE: Surface area surrounding open end of a cylinder or bearing bore.

BORE MISALIGNMENT: A condition existing when true centerline of two or more bores do not coincide with their common centerline. Can also refer to bore true centerline not being in desired alignment with some other part.

BORING: Renewing cylinders by cutting them out to a specified size. Boring bar is used to make cut.

BORING BAR (Cylinder): Machine used to cut engine cylinders to specific size. As used in garages, to cut worn cylinders to a new diameter.

BOSS: A rib or enlarged area designed to strengthen a certain portion or area of an object.

BOTTLED GAS: LPG (Liquefied Petroleum Gas) gas compressed into strong metal tanks. When confined in tank under pressure, gas is in liquid form.

BOUND ELECTRONS: Electrons in inner orbits around nucleus of atom. They are difficult to move out of orbit.

BOURDON TUBE: Circular, hollow piece of metal used in some instruments. Pressure on hollow section causes it to attempt to straighten. Free end then moves needle on gauge face.

BOWED CRANKCASE: A condition in which engine block warpage or distortion has actually bent crankcase, thus throwing crank bearing bores out of alignment.

BOWL VENT: A small hole near top of a carburetor float bowl. Used to allow air to move in or out as pressures dictate. Prevents formation of either pressure or vacuum above bowl fuel.

BOXED FRAME: A frame in which two channel shaped rails are welded together (open side to open side) forming a box shape providing great strength.

BOXED ROD: Connecting rod in which I-beam section has been stiffened by welding plates on each side of the rod.

BRAIDED COVER: A woven shielding placed around a wire, hose, etc., to provide additional strength, resistance to abrasion, etc.

BRAKE ANCHOR: Steel stud upon which one end of brake shoes is either attached to or rests against. Anchor is firmly affixed to backing plate.

BRAKE ANTI-ROLL DEVICE: Unit installed in brake system to hold brake line pressure when car is stopped on upgrade. When car is stopped on upgrade and brake pedal released, anti-roll device will keep brakes applied until either clutch is released or accelerator is depressed.

BRAKE BACKING PLATE: Rigid steel plate upon which brake shoes are attached. Braking force applied to shoes is absorbed by backing plate.

BRAKE BAND: Band, faced with brake lining, that encircles a brake drum. Used on several parking brake installations.

BRAKE BLEEDING: See Bleeding the Brakes.

BRAKE CONES: Tapered cones used to center brake drums and discs for refinishing on a brake grinder or lathe.

BRAKE CYLINDER: See Wheel Cylinder.

BRAKE – DISC TYPE: Braking system that instead of using conventional brake drum with internal brake shoes, uses steel disc with caliper type lining application. When brakes are applied, section of lining on each side of spinning disc is forced against disc thus imparting braking force. This type is very resistant to brake fade.

BRAKE DRUM: Cast iron or aluminum housing, bolted to wheel, that rotates around brake shoes. When shoes are expanded, they rub against machined inner surface of brake drum and exert braking effect upon wheel.

BRAKE DRUM LATHE: Machine to refinish inside of a brake drum.

BRAKE FADE: Reduction in braking force due to loss of friction between brake shoes and drum. Caused by heat buildup.

BRAKE FEEL: Discernible, to driver, relationship between the amount of brake pedal pressure and the actual braking force being exerted. Special device is used in power brake installations to give driver this feel.

BRAKE FLUID: Special fluid used in hydraulic brake systems. Never use anything else in place of regular fluid.

BRAKE FLUSHING: Cleaning brake system by flushing with alcohol or brake fluid. Done to remove water, dirt, or any other contaminant. Flushing fluid is placed in master cylinder and forced through lines and wheel cylinders where it exits at cylinder bleed screws.

BRAKE GRINDER: May refer to one of several machines used to true brake drums, discs (rotors), lining, etc., through removal of material by an abrasive device.

BRAKE HORSEPOWER (bhp): Measurement of actual usable horsepower delivered at crankshaft. Commonly computed using an engine on a chassis dynamometer.

BRAKE HOSE: Flexible hose which connects brake lines to wheel cylinders. It allows suspension movement without damage.

BRAKE LINE: Steel tubing which carries brake fluid from master cylinder to wheel cylinders.

BRAKE LINING: Friction material fastened to brake shoes. Brake lining is pressed against rotating brake drum, stopping car.

BRAKE – PARKING or EMERGENCY: Brake used to hold car in position while parked. One type applies rear brake shoes by mechanical means and other type applies brake band to brake drum in drive train.

BRAKE PEDAL HEIGHT: A measurement of distance between top face of brake pedal and floor.

BRAKE – POWER: Conventional hydraulic brake system that utilizes either engine vacuum or hydraulic pressure to operate a power piston. Power piston applies pressure directly to master cylinder piston. This reduces amount of pedal pressure driver must exert to stop car.

BRAKE SHOE GRINDER: Grinder used to grind brake shoe lining so it will be square to and concentric with brake drum.

BRAKE SHOE HEEL: End of brake shoe adjacent to anchor bolt or pin.

BRAKE SHOE TOE: Free end of shoe, not attached to or resting against an anchor pin.

BRAKE SHOES: Part of brake system, located at wheels, upon which brake lining is attached. When wheel cylinders are actuated by hydraulic pressure, they force brake shoes apart.

BRAKE SPECIALIST: A person highly trained and experienced in field of brake diagnosis, service, and repair.

BRAKES – POWER BOOSTER (Hydraulic): Brake booster employing hydraulic pressure from the power steering system to apply force to master cylinder.

BRASS DRIFT PUNCH: Punch, made of brass, used to drive shafts, pins, etc., in or out of their respective bores without damage.

BRASS HAMMER: Hammer made of brass. Useful for striking jobs in which a steel hammer could damage work.

BRAZE: To join two pieces of metal together by heating edges to be joined and then melting drops of brass or bronze on area. Unlike welding, this operation is similar to soldering, only a higher melting point material is used.

BRAZING FLUX: A powder or liquid used in brazing, that tends to remove scale and oxidization, allowing brazing metal to both flow and bond readily.

BRAZING ROD: Bronze, manganese bronze, silver alloy, etc., rods used in braze welding. Melts at a lower temperature than base metal.

BREAKAWAY TORQUE: When tightening a fastener, measurement of twisting force (torque) required to start a stuck or already tightened fastener turning. This torque is not a true indication of actual fastener torque as it will be higher than that used in initial tightening and higher than that required to keep it moving.

BREAK-IN: Period of operation between installation of new or rebuilt parts and time in which parts are worn to the correct fit. Driving at reduced and varying speed for a specified mileage to permit parts to wear to the correct fit.

BREAK-IN COATING: A special oil, additive, compound, etc., used on a new part to prevent scoring, overheating, seizing, etc., during the break-in period.

BREAK-OVER ANGLE: Included angle that a vehicle can cross over without dragging underneath center section. Break-over angle is determined by vehicle ground clearance and wheelbase.

BREAKER (Tire): Rubber or fabric (or both) strip placed under tread to provide additional protection for main tire carcass.

BREAKER ARM: Movable arm upon which one of breaker points is affixed.

BREAKER POINTS (Ignition): Pair of movable points that are opened and closed to break and make the primary circuit.

BREATHER PIPE: Pipe opening into interior of engine. Used to assist ventilation. Pipe usually extends downward to a point just below engine so passing air stream will form a partial vacuum thus assisting in venting engine.

BREATHER PORT (Master cylinder): A small hole in master cylinder cap or cover that allows air to move in or out of reservoir. This prevents either vacuum or pressure forming above reservoir brake fluid.

BRINELLING (Bearing): A condition in which an antifriction bearing race or ring has a series of dents or grooves worn in bearing surface.

BRINELL TEST: A test to determine relative hardness of a given material, such as steel. A hardened steel ball of a specific size (1 centimetre) is pressed into material under a specific pressure and surface area of resulting dent is determined, divided into load force, and indicated as a Brinell number.

BRISTLE BRUSH: A brush used for general cleaning. May use steel, brass, plastic, etc., bristles depending on type.

BROACH: Bringing metal surface to desired shape by forcing multiple-edged cutting tool across surface.

BRONZE: An alloy basically consisting of tin and copper.

BRUSH: Pieces of carbon, or copper, that rub against the commutator on generator and starter motor.

B&S GAUGE (Brown and Sharpe): Standard measure of wire diameter.

BTDC: Before Top Dead Center.

BTU (British thermal unit): Measurement of the amount of heat required to raise temperature of one pound of water, one degree Fahrenheit.

BUDC: Before Upper Dead Center. Same as BTDC.

BULKHEAD UNION: A pipe union (connector) designed to connect two pipes on opposite sides of a bulkhead (divider) such as an engine compartment fire wall.

BUNA: Synthetic (manufactured) rubber.

BUNSEN BURNER: Small gas (propane, natural) burner, as commonly used in laboratories.

BURNISH: To bring a surface to a high shine by rubbing with hard, smooth object.

BURNISHED TO SIZE: Bringing an object such as a bushing, to its final size by rubbing with a very hard, smooth tool.

BURNISHING TOOL: A very smooth, hard surfaced tool used to rub a metal surface to produce a dense, extremely smooth finish.

"BURN OIL": An expression used to indicate process of an engine leaking oil past rings into combustion chamber where it is burned.

BUSHING: Bearing for shaft, spring shackle, piston pin, etc., of one piece construction which may be removed from part.

BUTANE: Petroleum gas that is liquid, when under pressure. Often used as fuel in trucks.

BUTT CONNECTOR (Electrical): An insulated connecting device (either crimp or solder type) used to join ends of two wires together.

BUTTERFLY VALVE: Valve in carburetor that is so named due to its resemblance to insect of same name.

BUTT WELD: Joining two pieces of metal by placing them edge to edge and welding along junction line.

BYPASS: To move around or detour regular route or circuit taken by air, fluid, electricity, etc.

BY-PASS FILTER: Engine oil filter that constantly filters PORTION of oil.

BY-PASS VALVE: Valve that can open and allow fluid to pass through in other than its normal channel.

C

CAFE: Corporate Average Fuel Economy.

CAGE (Bearing): An enclosure, often stamped steel, that retains, separates, and spaces bearing balls or rollers.

CALIBRATE: As applied to test instruments – adjusting dial needle to correct zero or load setting.

CALIPER (Brake): Disc brake component which forms cylinder and houses piston and brake pads (linings). It produces clamping action on rotating disc to stop car.

CALIPER ALIGNMENT: Refers to brake caliper alignment in relation to brake disc (rotor). Caliper pistons-brake pads must be at right (90°) angles to disc braking surface and on fixed calipers, centered over disc.

CALIPERS (Inside and outside): Adjustable measuring tool placed around or within an object and adjusted until it just contacts. It is then withdrawn and distance measured between contacting points.

CALORIE (Gram): A unit of heat. Amount of heat required to raise the temperature of one gram of water 1 deg. centigrade.

CALORIFIC VALUE: Measurement of the heating value of fuel.

CALORIMETER: Measuring instrument used to determine amount of heat produced when a substance is burned; also friction and chemical change heat production.

CAM: Offset portion of shaft that will, when shaft turns, impart motion to another part such as valve lifters.

CAM ANGLE or DWELL (Ignition): Number of degrees breaker cam rotates from time breaker points close until they open again.

CAMBER: Tipping top wheel centerline outward produces positive camber. Tipping wheel centerline inward at top produces negative camber. When camber is positive, tops of tires are further apart than bottom.

CAM FLANK (Camshaft): That portion of a cam lobe between cam nose and point at which opening action occurs or closing action stops.

CAM GROUND: Piston ground slightly egg-shaped. When heated, it becomes round.

CAM LOBE LIFT (Camshaft): A measurement of amount of travel cam will impart to lifter from full closed (lifter on base circle) to full open (lifter on tip of cam nose).

CAM NOSE (Camshaft): Tip or highest point on a cam lobe.

CAMSHAFT: Shaft with cam lobes (bumps) used to operate valves.

CAMSHAFT END PLAY: A measurement of longitudinal (end to end) movement of camshaft.

CAMSHAFT GEAR: Gear that is used to drive camshaft.

CAMSHAFT RUNOUT: A measurement of amount of bend existing in a camshaft.

CAMSHAFT SPROCKET: Toothed device attached to camshaft and meshed with drive chain or belt.

CAMSHAFT THRUST PLATE: A flat plate designed to control thrust force and amount of end movement or play.

CANDELA: A unit of measure for light intensity.

CANDLE POWER: Measurement of light producing ability of light bulb.

CAP: Cleaner Air Package System of reducing amount of unburned hydrocarbons in automobile exhaust.

CAPACITANCE: Property of condenser that permits it to receive and retain an electrical charge.

CAPACITOR: See Condenser.

CAPILLARY ACTION: Movement of liquid along surface of a solid. Caused by state of surface tension (attraction) existing between molecules of liquid and solid.

CAPILLARY TUBE: A very fine tube with a tiny hole. Capillary action (liquid movement into tube) can take place.

CAP PARTING EDGES (Bearing): That portion of a bearing cap that presses against other bearing half when cap is installed.

CAP SCREW: A headed fastener that passes through one part and threads into another. When cap screw is tightened parts are drawn together. No nut is required.

CARB: California Air Resources Board.

CARBON: Used to describe hard, or soft, black deposits found in combustion chamber, on plugs, under rings, on and under valve heads, etc.

CARBON ARC: Flow of electricity across a gap between two electrodes one of which must be made of carbon.

CARBON DIOXIDE: A tasteless, odorless, colorless gas (CO_2). Used in carbonated drinks, some fire extinguishers, etc.

CARBONIZE: Building up of carbon on objects: spark plugs, pistons, heads, etc.

CARBON MONOXIDE: Deadly, colorless,

odorless, and tasteless gas found in engine exhaust. Formed by incomplete burning of hydrocarbons.

CARBON PILE: Refers to amperage or voltage regulator utilizing a stack of carbon discs in its construction.

CARBON SOLVENT: A cleaning solvent especially formulated to loosen and remove carbon deposits.

CARBON TRACKING (Electrical): Carbon trail along a path of electrical current flashover such as is formed by current flow between insulated terminals of a distributor cap.

CARBURETOR: Device used to mix gasoline and air in correct proportions.

CARBURETOR ADAPTER: Adapter used to fit or place one type of carburetor on an intake manifold that may not be originally designed for it. Also used to adapt four-barrel carbs to two-barrel manifolds.

CARBURETOR CIRCUITS: Series of passageways and units designed to perform a specific function—idle circuit, full power circuit, etc.

CARBURETOR ICING: Formation of ice on throttle plate or valve. As fuel nozzles feed fuel into air horn, it turns to a vapor. This robs heat from air and when weather conditions are just right (fairly cold and quite humid), ice may form.

CARBURIZING FLAME: Welding torch flame with an excess of acetylene.

CARCASS PLY: Tire main body plies.

CARDAN JOINT: Type of universal joint.

CARRIER BEARINGS: Bearings upon which differential case is mounted.

CASE-HARDENED: Piece of steel that has had outer surface hardened while inner portion remains relatively soft.

CASTER: Tipping top of kingpin either forward or toward the rear of car. When tipped forward, it is termed negative caster. When tipped toward rear, it is positive caster.

CASTING: Pouring metal into a mold to form an object.

CASTLE or CASTELLATED NUT: Nut having series of slots cut into one end. Cotter pin may be passed through to secure nut.

CATALYTIC CONVERTER: Device used in exhaust system to reduce harmful emissions. Catalyst in converter may be coated with palladium, platinum, and rhodium. Catalyst may be of oxidizing and/or reducing design.

CATHODE: In electric circuit—the negative pole.

CAUSTIC: Compound, solution, etc., that will cause burning and corrosion.

CCS: Controlled Combustion System of reducing unburned hydrocarbon emission from engine exhaust.

CEC: Combination Emission Control.

CELL (Battery): Individual (separate) compartments in battery which contain positive and negative plates suspended in electrolyte. Six-volt battery has three cells, twelve-volt battery has six cells.

CELL CONNECTOR: Lead strap or connection between battery cell groups.

CENTERING SLEEVE: Sleeve passed over engine crankshaft front portion to align timing cover prior to tightening fasteners.

CENTERING SOCKET (U-joint): Central socket of a constant speed universal joint. It tends to keep both halves of joint operating in a plane that forms one-half of operating angle.

CENTERLINE: Imaginary line drawn lengthwise through center of an object.

CENTER LINK: Also called relay rod or connecting link, it transfers motion from pitman arm to tie rods.

CENTER OF GRAVITY: Point in object, if through which an imaginary pivot line were drawn, would leave object in balance. In car, the closer the weight to the ground, the lower the center of gravity.

CENTER PUNCH: A sharp nosed punch used to form a small "V" shaped depression so as to properly align a drill bit prior to actual drilling.

CENTER STEERING LINKAGE: Steering system utilizing two tie rods connected to steering arms and to central idler arm. Idler arm is operated by drag link that connects idler arm to pitman arm.

CENTER SUPPORT BEARING (Propeller shaft): A bearing used for central support of long, two-piece propeller shafts.

CENTIGRADE: Thermometer on which boiling point of water is 100 deg. and freezing point is 0 deg.

CENTRIFUGAL ADVANCE (Distributor): Unit designed to advance and retard ignition timing through action of centrifugal force.

CENTRIFUGAL CLUTCH: Clutch that utilizes centrifugal force to expand a friction device on driving shaft until it is locked to a drum on driven shaft.

CENTRIFUGAL FORCE: Force which tends to keep moving objects traveling in straight line. When moving car is forced to make a turn, centrifugal force attempts to keep it moving in straight line. If car is turning at too high a speed, centrifugal force will be greater than frictional force between tires and road and the car will slide off the road.

CERAMIC FILTER: Filtering device utilizing porous ceramic as filtering agent.

CERAMIC SUBSTRATE: A ceramic material, covered with aluminum oxide, that forms base upon which palladium, platinum, etc., are applied. Used in one type of catalytic converter construction.

CETANE NUMBER: Measurement of diesel fuel performance characteristics.

CFM: Cubic feet per minute. A measure of air flow.

CHAIN HOIST: A lifting device employing an endless chain running through two or more chain sheaves.

CHAIN LINK PIN: Pin passing through engine timing chain link sections.

CHAIN SLACK: A measurement of amount of "play" or looseness in a timing chain. Generally determined by measuring chain deflection.

CHAIN TENSIONER: A device used to reduce slap and flutter from a timing chain by removing slack. Device can be either fixed or spring-loaded.

CHAMFER: To bevel (or a bevel on) edge of an object.

CHANGE OF STATE: Condition in which substance changes from a solid to a liquid, a liquid to a gas, a liquid to a solid, or a gas to a liquid.

CHARCOAL CANISTER: Emission control device containing activated charcoal granules. Used to store gasoline vapors from tank and carburetor. When engine is started, stored vapors are drawn into cylinders and burned.

CHARGE (Air conditioning): A given or specified (by weight) amount of refrigerant.

CHARGE (Battery): Passing electric current through battery to restore it to active (charged) state.

CHARGE RATE: Electrical rate of flow, in amperes, passing through the battery during charging.

CHARGING (Air conditioning): Inserting the specified charge (amount) of refrigerant into the air conditioning system.

CHARGING STATION: A complete portable setup—R-12 tank, gauges, hoses, etc., that is used to service automotive air conditioning systems.

CHASE: To repair damaged threads.

CHASSIS: Generally, chassis refers to frame, engine, front and rear axles, springs, steering system, and gas tank. In short, everything but body and fenders.

CHASSIS DYNAMOMETER: See Dynamometer.

CHATTER (Tool): A vibrating, bouncing motion. When applied to cutting tools, tool will leave an uneven surface made up of fine ridges.

CHECK VALVE: Valve that opens to permit passage of fluid or air in one direction and closes to prevent passage in opposite direction.

CHILLED IRON: Cast iron possessing hardened outer skin.

CHLORIDE FLUX: An acid (hydrochloric) type soldering flux. Do not use on wiring.

CHOKE: Butterfly valve located in carburetor used to enrichen mixture for starting engine when cold.

CHOKE "BREAK": A device, electrical or vacuum operated, designed to partially open carburetor choke when the engine starts.

CHOKE STOVE: Heating compartment in or on exhaust manifold from which hot air is drawn to automatic choke device.

CID: Cubic Inch Displacement.

CIRCUIT (Electrical): Source of electricity (battery), resistance unit (headlight, etc.) and wires that form path for flow of electricity from source, through unit and back to source.

CIRCUIT BREAKER (Lighting system): Protective device that will make and break flow of current when current draw becomes excessive. Unlike fuse, it does not blow out but vibrates on and off thus giving driver some light to stop by.

CIRCULAR MIL: A unit of measurement equal to cross-sectional area of a circle one mil in diameter. One mil equals 0.001 in. Used to indicate wire size.

CLASS (Bolt): A description of thread fit between bolt and nut. Of three classes (1, 2, and 3), class 1 is quite loose, class 2 normal fit as used on automotive applications, and class 3 is very close.

CLEARANCE: Given amount of space between two parts—between piston and cylinder, bearing and journal, etc.

CLEVIS PIN: A pin passing through each side of clevis (yoke) open end.

CLINCH JOINT (Bearing): A bearing made by rolling steel backing into a round tube with a dovetail protrusion locking mating edges together.

CLOCKWISE: Rotation to right as that of clock hands.

CLOSED COOLING SYSTEM: Type of system which uses an overflow tank.

CLOSED LOOP FUEL SYSTEM: A fuel

system in which air-fuel ratio is constantly adjusted in relationship to hydrocarbon content of exhaust. An oxygen sensor in exhaust, working through an electronic control unit, alters either carburetor jet size or fuel injection system pulse width.

CLUSTER or COUNTER GEAR: Cluster of gears that are all cut on one long gear blank. Cluster gears ride in bottom of transmission. Cluster provides a connection between transmission input shaft and output shaft.

CLUTCH: Device used to connect or disconnect flow of power from one unit to another.

CLUTCH ARBOR: A round steel shaft, one end of which is slipped into flywheel clutch pilot bearing or bushing. Diameter of remainder fits inside of clutch disc splines. Arbor aligns disc with flywheel friction surface while pressure plate is installed.

CLUTCH COVER: That portion of clutch that surrounds and secures pressure plate assembly. Cover bolts to flywheel.

CLUTCH DIAPHRAGM SPRING: Round dish-shaped piece of flat spring steel. Used to force pressure place against clutch disc in some clutches.

CLUTCH DISC: Part of clutch assembly splined to transmission clutch or input shaft. Faced with friction material. When clutch is engaged, disc is squeezed between flywheel and clutch pressure plate.

CLUTCH DISC DAMPER SPRING: A series of coil springs located between disc hub and disc proper. Springs soften impact to clutch shaft when disc is seized between pressure plate and flywheel.

CLUTCH DISC HUB: Central splined portion of clutch disc.

CLUTCH EXPLOSION: Clutches have literally flown apart (exploded) when subjected to high rpm. Scatter shield is used on competition cars to protect driver and spectators from flying parts in event clutch explodes.

CLUTCH FRICTION SURFACE: Refers to areas of clutch that rub against disc friction facing.

CLUTCH HOUSING or BELL HOUSING: Cast iron or aluminum housing that surrounds flywheel and clutch mechanism.

CLUTCH LINKAGE: Mechanism which transfers movement from clutch pedal to throw-out fork.

CLUTCH PEDAL FREE TRAVEL: Specified distance clutch pedal may be depressed before throw-out bearing actually contacts clutch release fingers.

CLUTCH PEDAL HEIGHT: A measurement from top face of pedal to floor mat.

CLUTCH PILOT BEARING: Small bronze bushing, or in some cases ball bearing, placed in end of crankshaft or in center of flywheel depending on car, used to support outboard end of transmission input shaft.

CLUTCH PRESSURE PLATE: Part of a clutch assembly that through spring pressure, squeezes clutch disc against flywheel thereby transmitting driving force through the assembly. To disengage clutch, pressure plate is drawn away from flywheel via linkage.

CLUTCH RELEASE FINGERS: Steel fingers on pressure plate assembly that, when depressed by throw-out bearing, pull pressure plate away from clutch disc.

CLUTCH SEMI-CENTRIFUGAL RELEASE FINGERS: Clutch release fingers that have a weight attached to them so that at high rpm release fingers place additional pressure on clutch pressure plate.

CLUTCH THROW-OUT FORK: Device or fork that straddles throw-out bearing and used to force throw-out bearing against clutch release fingers.

CO: Symbol for carbon monoxide.

COAST PATTERN (Ring and pinion): Contact pattern (area of contact between differential ring and pinion gear) when vehicle is coasting (car driving engine).

COIL (Ignition): Used to step up battery voltage to point necessary to fire spark plugs.

COIL CORE: Multilayered mass of iron around which coil windings are wrapped. Some designs place core outside of windings.

COIL POLARITY: Refers to ignition coil (Neg. or Pos.) primary connection hookup. Battery and coil polarity must be same. When battery NEG. is grounded, coil NEG. must be connected to ground through distributor.

COIL SPRING: Section of spring steel rod wound in spiral pattern or shape. Widely used in both front and rear suspension.

COLD: Little or no perceptible heat.

COLD BENDING: Bending a part without heating it first.

COLD CLEARANCE SETTING (Valves): Adjusting valve lash or clearance when engine is at room temperature.

COLD CRANKING RATING (Battery): Measurement of cranking amperes that a battery can deliver over a period of 30 seconds at 0°F (−17.8°C) and still maintain a minimum cell voltage of 1.2 volts.

COLD EXPANDING (Piston): Expanding an engine piston by mechanical means and without use of heat.

COLD FLOW (Gasket): Excessive fastener torque causing gasket to flatten and extrude outward.

COLD SOAK CLEANING: Immersing parts in a cold cleaner bath for recommended time period to help loosen and remove carbon, dirt, grease, etc.

COLD START INJECTOR: Fuel injector which sprays additional fuel for cold engine starting.

COLD START VALVE (Fuel Injection): A valve used on certain gasoline fuel injection systems. Valve supplies additional flow of fuel during cold starting conditions.

COLLAPSED (Piston): Piston whose skirt diameter has been reduced due to heat and forces imposed upon it during service.

COLLAPSIBLE PRELOAD SPACER: A special spacer as used between bearings on some differential drive pinion shafts. When nut is torqued to specs, spacer will collapse a specified amount and will thus provide an initial (before torque loading) load (preload) on bearings.

COLLECTOR RING (Alternator): Rings (also called "slip" rings) mounted on rotor. Brushes rub against collector rings and "collect" electrical current produced by alternator.

COLOR CODING (Wiring): Using various colors to identify specific wiring circuits. Wiring diagrams show circuits and specify color.

COMBINATION VALVE (Brakes): A dual purpose valve that can combine proportioning, metering, and pressure differential warning functions.

COMBUSTION: Process involved during burning.

COMBUSTION CHAMBER: Area above piston with piston on TDC. Head of piston, cylinder, and head form the chamber.

COMBUSTION CHAMBER VOLUME: Volume of combustion chamber (space above piston with piston on TDC) measured in cc (cubic centimetres).

COMMUTATOR: Series of copper bars connected to armature windings. Bars are insulated from each other and from armature. Brushes (as in generator or starter) rub against whirling commutator.

COMMUTATOR SEGMENT OR BAR (Starter): Copper bars connecting armature windings to brushes.

COMPENSATING PORT: Small hole in brake master cylinder to permit fluid to return to reservoir.

COMPENSATOR VALVE (Automatic transmission): Valve designed to increase pressure on brake band during heavy acceleration.

COMPOUND: Two or more ingredients mixed together.

COMPOUND PLANETARY GEARSET: Refers to use of combination of two or more planetary gearsets in a single assembly.

COMPRESSIBILITY: Ability of a material to be flattened by applying pressure. Compressibility of steel is low, cork is high.

COMPRESSION: Applying pressure to a spring, or any springy substance, thus causing it to reduce its length in direction of compressing force. Applying pressure to gas, thus causing reduction in volume.

COMPRESSION CHECK: Testing compression in all cylinders at cranking speed. All plugs are removed, compression gauge placed in one plug hole, throttle cracked wide open, and engine cranked until gauge no longer climbs. Compression check is a fine way in which to determine condition of valves, rings, and cylinders.

COMPRESSION CONNECTION (Tubing): A flareless tubing fitting using a tapered edge sleeve that, when squeezed between the fitting body and nut, pinches tubing to produce a seal. Another type uses sleeve function as an intergral nose on nut.

COMPRESSION GAUGE: Gauge used to test compression in engine cylinders.

COMPRESSION LOADING (Ball joint): A front suspension ball joint arrangement that, when under loading forces, causes ball joint parts to be compressed together. Tension loading attempts to pull ball out of socket.

COMPRESSION RATIO: Relationship between cylinder volume (clearance volume) when piston is on TDC and cylinder volume when piston is on BDC.

COMPRESSION RING GROOVE (Piston): Groove cut into piston head to accept a compression ring.

COMPRESSION RINGS: Top piston rings, generally two, designed to seal between piston and cylinder to prevent escape of gas from combustion chamber.

COMPRESSION STROKE: Portion of piston's movement devoted to compressing the fuel mixture trapped in engine's cylinder.

COMPRESSION TESTER: Gauge used to check engine compression pressure.

COMPRESSOR (Air conditioning): Device using a series of pistons to raise pressure of refrigerant in system. Also causes refrigerant to flow through system.

COMPRESSOR PROTECTION SWITCH (Air conditioning): A heat and/or pressure sensitive switch to protect compressor from damage caused by loss of oil and overheating.

COMPUTERIZED DIAGNOSTIC UNIT: An electrical diagnostic unit that receives input from numerous sensors and then automatically, through pre-programming, determines possible problems. Advanced units detect problems, and suggest possible corrections and/or further tests. Some provide printout sheets.

COMPUTERIZED IGNITION: Ignition system using sensors which feed electrical information to computer. Computer then controls ignition system and sometimes other functions (carburetor, fuel injection, transmission) for maximum efficiency.

COMPUTERIZED RIDE CONTROL (ACTIVE SUSPENSION): Advanced suspension system that can adapt to specific driving conditions.

CONCENTRIC: Two or more circles so placed as to share common center.

CONCENTRIC GRINDING (Brakes): Grinding brake lining (mounted on shoe) contour so that it matches that of brake drum. Gives full contact between drum and shoe.

CONDENSE: Turning vapor back into liquid.

CONDENSER (Ignition): Unit installed between breaker points and coil to prevent arcing at breaker points. Condenser has ability to absorb and retain surges of electricity.

CONDENSER (Refrigeration): Unit in air conditioning system that cools hot compressed refrigerant and turns it from vapor into liquid.

CONDENSATION: Moisture, from air, deposited on a cool surface.

CONDUCTION: Transfer of heat from one object to another by having objects in physical contact.

CONDUCTOR: Material forming path for flow of current.

CONE CLUTCH: Clutch utilizing cone-shaped member that is forced into a cone-shaped depression in flywheel, or other driving unit, thus locking two together. Although no longer used on cars, cone clutch finds some applications in small riding tractors, heavy power mowers, etc.

CONNECTING ROD: Connecting link between piston and crankshaft.

CONNECTING ROD ALIGNER: Tool designed to check rod for twist and bend.

CONNECTING ROD BEARINGS: Inserts which fit into connecting rod and ride on crankshaft journals.

CONNECTING ROD BEND: A condition in which centerlines of rod pin bore and big end bearing bore are not parallel – as viewed from edge of an upright rod.

CONNECTING ROD CAP: Lower removable part of rod which holds lower bearing insert.

CONNECTING ROD JOURNAL: That portion of crankshaft riding in and contacting connecting rod bearing.

CONNECTING ROD SIDE PLAY: Amount of sliding movement determined by measuring distance rod can be moved from full forward to full rearward position.

CONNECTING ROD SPIT HOLE: Small hole drilled through upper portion of connecting rod big end. Allows oil to squirt or spurt out to lubricate a specific area, such as cylinder, camshaft, etc.

CONNECTING ROD STRAIGHTENER: Tool used to remove connecting rod twist, bend, or offset.

CONNECTING ROD TWIST: A condition in which centerline of rod pin bore is turned either to left or right, as related to centerline of rod big end bore – as viewed looking downward on an upright rod.

CONSTANT DRIVE OVERDRIVE: An overdrive unit that, when engaged, is constantly connected to drive wheels and will not permit freewheeling (coasting).

CONSTANT MESH GEARS: Gears that are always in mesh with each other.

CONSTANT VELOCITY UNIVERSAL JOINT: Universal joint so designed as to effect smooth transfer of torque from driven shaft to driving shaft without any fluctuations in speed of driven shaft.

CONTACT POINTS also called BREAKER POINTS: Two removable points or areas that when pressed together, complete circuit. These points are usually made of tungsten, platinum, or silver.

CONTINUITY (Electrical): Refers to an electrical circuit in which all contacting parts are clean and tight, so as to permit desired current flow.

CONTINUOUS FUEL INJECTION: A fuel injection system in which injectors are always open and as such, feed fuel constantly. Amount of fuel delivered can be determined by an airflow sensor.

CONTRACTION (Thermal): Reduction in size of object when cooled.

CONTROL ARM (Suspension): a pivoting arm that maintains alignment of an axle, steering knuckle assembly, etc., while permitting needed movement.

CONTROL MODULE: Small computer used to control specific systems within an automobile. Control modules are generally used to govern the air bag and anti-lock brake systems.

CONTROL RACK: Toothed rod inside mechanical injection pump which rotates pump plunger to control quantity of injected fuel.

CONTROL VALVE: A movable valve in an air, fluid, etc., line, that is designed to start, stop, or alter movement, speed, volume, direction, etc.

CONVECTION: Transfer of heat from one object to another when hotter object heats surrounding air and air heats other object.

COOLANT: Liquid in cooling system.

COOLANT TEMPERATURE OVERRIDE SWITCH (CTO): Coolant controlled vacuum switch that cuts off engine vacuum to EGR valve when engine temperature is below a specified point.

COOLING SYSTEM: System, air or water, designed to remove excess heat from engine.

COOLING SYSTEM SCALE: A coating of rust, mineral, etc., deposited in both engine coolant jacket and radiator. If heavy, interferes with coolant flow and causes overheating.

"COPPER" (Soldering): A soldering iron utilizing a relatively heavy copper block attached to a metal shaft with insulated handle. Tinned copper is placed in a flame for heating.

CORE: When referring to casting – sand unit placed inside mold so that when metal is poured, core will leave a hollow shape.

CORE HOLE PLUG: A metal plug (sometimes called "freeze" plug) pressed into holes in engine water jacket casting sand core holes.

CORONA (Electrical): Luminous discharge of electricity visible near surface of an electrical conductor under high voltage.

CORRODE: Removal of surface material from object by chemical action.

COTTER KEY (Pin): A split pin that is inserted through a hole in a shaft, bolt, etc. Ends are spread apart to prevent key from falling out. Used to secure nuts, clevis pins, shafts, etc.

COUNTERBALANCE: Weight attached to some moving part so part will be in balance.

COUNTERBORE: Enlarging hole to certain depth.

COUNTERCLOCKWISE: Rotation to the left as opposed to that of clock hands.

COUNTERSHAFT: Intermediate shaft that receives motion from one shaft and transfers it to another. It may be fixed (gears turn on it) or it may be free to revolve.

COUNTERSINK: To make a counterbore so that head of a screw may set flush, or below the surface.

COUNTERWEIGHT: A weight, integral or attached, affixed to a part such as a crankshaft, to bring revolving mass into balance.

COUPLING: Connecting device used between two objects so motion of one will be imparted to other.

COUPLING POINT: This refers to point at which both pump and turbine in torque converter are traveling at same speed. The drive is almost direct at this point.

COWL: Part of car body between engine firewall and front of dash panel.

"CRACK" A FITTING: To slowly open a fitting a small amount.

CRACK DETECTION: Using X ray, chemical solution, magnetic field, etc., to locate otherwise unseen fractures or cracks in a metal part.

CRACK PINNING: Repairing a crack, such as in a cylinder head, by installing a series of overlapping threaded pins. They are cut off and filed flush with surface.

CRANKCASE: Part of engine that surrounds crankshaft. Not to be confused with the pan which is a thin steel cover that is bolted to crankcase.

CRANKCASE DILUTION: Accumulation of unburned gasoline in crankcase. Excessively rich fuel mixture or poor combustion will allow some of gasoline to pass down between pistons and cylinder walls.

CRANKCASE VENTILATION: Process of drawing clean air through interior of engine to remove blow-by gases and other fumes.

CRANKCASE WEB: A thin, reinforcing wall cast as integral part of the crankcase to provide rigidity for main bearing bores.

CRANK GRINDER: A machine used to grind crankshaft journals to highly accurate dimensions.

CRANKING MOTOR: Starter. Device to revolve engine crankshaft to start engine. Works through a gear engaging another gear on flywheel.

CRANKING VACUUM TEST: An engine test that determines basic engine (piston, ring, cylinder, valve) condition by measuring amount of vacuum developed in engine cylinders during cranking.

CRANKSHAFT: Shaft running length of engine. Portions of shaft are offset to form throws to which connecting rods are attached. Crankshaft is supported by main bearings.

CRANKSHAFT GEAR: Gear mounted on front of crankshaft. Used to drive camshaft gear.

CRANKSHAFT MICROMETER: A micrometer designed to measure crankshaft main bearing journal diameter while the crankshaft is in place (main cap off).

CRANKSHAFT SPROCKET: Timing chain sprocket attached to one end of crankshaft.

CRANKSHAFT THROW: Offset part of crankshaft where connecting rods fasten.

CRANKSHAFT THRUST FACE: Precision ground portion of crankshaft, at right angles to ends of main bearing journal, that operates against main bearing thrust surface. Controls end play.

CRIMPED TERMINAL: An electrical connector into which wire is inserted. Connector body is then forced inward at one or more points, thus gripping wire tightly.

CROCUS CLOTH: A very fine abrasive cloth using a coating of iron oxide particles.

CROSS AND ROLLER: Type of universal joint using a center cross (spider) mounted in needle bearings.

CROSS BOLT SPACER (Crankshaft): On engines employing a transverse stiffening bolt through both main bearing cap and crankcase, spacer is used between two sides of cap and crankcase walls. Prevents crankcase damage when tightening bolt.

CROSS FIRING: A condition in which firing of a given spark plug fires an additional plug. Caused by voltage from one wire being imparted to another by poor insulation or by improper routing of plug wires.

CROSS SHAFT (Steering): Shaft in steering gearbox that engages steering shaft worm. Cross shaft is splined to pitman arm.

CROSSHATCH FINISH (Cylinder): Pattern left in an engine cylinder bore by honing. Fine, visible circumferential scratch line cross one another at an angle. Angle depends upon hone rpm and number of up and down strokes in a given period of time.

CROSS-THREADING: Mismating of screw threads caused by engaging threads when their respective centerlines are not aligned. Will cause threads to jam and continued turning will ruin one or both threads.

CROSS UNION (Pipe): A four-way pipe connector in which any given connection is at right angles to adjacent connections.

CRUDE OIL: Petroleum in its raw or unrefined state. It forms the basis of gasoline, engine oil, diesel oil, kerosene, etc.

CUBES: Cubic inches, or cubic inch displacement of an engine.

CU. IN. (C.I.): Cubic inch.

CUNO FILTER: Filter made up of a series of fine discs or plates pressed together in a manner that leaves very minute space between discs. Liquid is forced through these openings to produce straining action.

CUP DRIVER (Bearing): A tool designed to install bearing cups (outer ring) in axles, front wheel bearing housing, etc.

CUP RACEWAY (Bearing): That portion of bearing cup (ring) designed to operate against bearing balls or rollers.

CURB HEIGHT: Indicates height of an automobile without passengers but with full fuel load. Measured from roadway surface to a specified location on car undercarriage.

CURB WEIGHT: Full operating (oil, coolant installed) weight of a vehicle without passengers but including a full tank of fuel.

CURRENT: Movement of free electrons through conductor.

CURRENT DRAW: Amount of current flow through a given electrical device when connected to a circuit.

CUSHION SPRING (Clutch): A series of coil springs located between clutch disc hub and clutch disc. Springs soften shock when clutch is engaged.

CUTOUT (Regulator): Device to connect or disconnect generator from battery circuit. When generator is charging, cutout makes circuit. When generator stops, cutout breaks circuit. Also referred to as cutout relay and circuit breaker.

CYCLE: Reoccuring period during which series of events take place in definite order.

CYLINDER: Hole, or holes, in cylinder block that contain pistons.

CYLINDER BALANCE TEST: Process of checking engine rpm and vacuum while operating engine on selected pairs of cylinders at a time. Do not use this test on catalytic converter equipped vehicles.

CYLINDER BLOCK: See Block.

CYLINDER BORE: See Bore.

CYLINDER DIAL GAUGE: A dial gauge measuring instrument designed to check engine cylinder bore diameters.

CYLINDER HEAD: Metal section bolted on top of block. Used to cover tops of cylinders. In many cases cylinder head contains the valves. Also forms part of combustion chamber.

CYLINDER HONE: Tool that uses an abrasive to smooth out and bring to exact measurement items such as engine cylinders, wheel cylinders, bushings, etc.

CYLINDER LEAKAGE TESTER: A special test tool used to check cylinder, ring, piston, valve, etc., condition by pressurizing a given cylinder (piston TDC on compression) to a given point with compressed air. Gauge then checks percentage of leakage.

CYLINDER LINER: See Cylinder Sleeve.

CYLINDER SLEEVE: Replaceable cylinder. It is made of a pipe-like section that is either pressed or pushed into the block.

CYLINDER STROKE: See Stroke.

D

DAMPER: A unit or device designed to remove or reduce vibration, oscillation, etc., of a moving part, fluid, air, etc.

DAMPER SPRING (Valve): A coil spring, installed inside regular valve spring, that helps to reduce spring vibration.

DASHBOARD: Part of body containing driving instruments, switches, etc.

DASHPOT: Unit utilizing cylinder and piston, or cylinder and diaphragm, with small vent hole, to retard or slow down movement of some part.

DC (Electrical): Direct Current.

DC (Piston position): Dead Center. Piston at extreme top or bottom of its stroke.

DEAD AXLE: Axle that does not rotate but merely forms base upon which to attach wheels.

DEAD CENTER (Engine): Point at which piston reaches its uppermost or downmost position in cylinder. Rod crank journal would be at 12 o'clock UDC or 6 o'clock LDC.

DECELERATION: Process of slowing down in rotational speed, forward speed, etc.

DECELERATION VALVE: It feeds air into intake manifold to prevent backfiring during deceleration.

DECIBEL: A unit of measurement used to indicate a sound level or to indicate the difference in specific sound levels.

DEEP GROOVE BALL: A ball bearing in which balls engage a rather deep groove in both inner and outer rings. Bearing will handle heavy radial and moderate thrust loads.

DEFLECTION RATE (Springs): Measurement of force, in lbs., required to compress leaf spring a distance of one inch.

DEGLAZER: Abrasive tool used to remove glaze from cylinder walls so a new set of rings will seat.

DEGREE (Circle): 1/360 part of a circle.

DEGREE WHEEL: Wheel-like unit attached to engine crankshaft. Used to time valves to a high degree of accuracy.

DEHUMIDIFY: Act of removing a certain amount of moisture from air.

DEHYDRATE: To dry out. Remove moisture.

DEMAGNETIZE: Removing residual magnetism from an object.

DEPOLARIZE: Removal of residual magnetism thereby destroying or removing the magnetic poles.

DEPTH TYPE FILTER (Engine oil): An engine oil filter utilizing a relatively thick layer of fibrous materials to filter out dirt, metal particles, etc. Entire layer acts as a filter with particles lodging at different depths.

DESICCANT: Material, such as silica-gel, placed within a container to absorb and retain moisture.

DETENT BALL AND SPRING: Spring loaded ball that snaps into a groove or notch to hold some sliding object in position.

DETERGENT: Chemical added to engine oil to improve its characteristics (sludge control, nonfoaming, etc.).

DETONATION: Fuel charge firing or burning too violently, almost exploding.

DEVELOPER SOLUTION (Fluorescent penetrant): Solution used to draw fluorescent crack detection penetrant to surface so that the application of black light will make presence of any cracks readily visible.

DIAGNOSIS: Process of analyzing certain symptoms, readings, etc., in order to determine underlying reason for trouble at hand.

DIAGNOSTIC LINK: A built-in electrical connector used to attach a diagnostic test instrument.

DIAL GAUGE OR INDICATOR: Often used precision micrometer type instrument that indicates exact reading via needle moving across dial face.

DIAMOND BORED: Surface of cylinder has been brought to size by removal of material with a diamond faced cutting tool.

DIAMOND TIPPED DRESSER: A stone dresser using a small piece of diamond attached to tip. Used to smooth and reface grinding stones.

DIAPHRAGM: Flexible cloth-rubber sheet stretched across an area thereby separating two different compartments.

DIAPHRAGM SPRING (Clutch): A clutch pressure plate spring device that, instead of using several coil springs, employs a single, cone-shaped piece of sheet spring steel. Depressing cone center lifts outer edge removing pressure. Release center and outer circumference pushes on pressure plate.

DICHLORODIFLUOROMETHANE: Refrigerant-12 used in air conditioning system.

DIE (Forming): One of a matched pair of hardened steel blocks that are used to form metal into a desired shape.

DIE (Thread): Tool for cutting threads.

DIE CASTING: Formation of object by forcing molten metal, plastic, etc., into die.

DIELECTRIC: A material, such as glass, rubber, etc., that resists flow of electricity. An insulator.

DIESEL ENGINE: Internal combustion engine that uses diesel oil for fuel. True diesel does not use an ignition system but injects diesel oil into cylinders. Piston compresses air so tightly that air is hot enough to ignite diesel fuel without spark.

DIESEL INJECTOR: A nozzle device for spraying diesel fuel into precombustion chamber.

DIESEL FUEL GRADE: Classification of diesel fuel operating characteristics, 1-D is for cold weather and 2-D is for normal conditions.

DIESEL INJECTION PUMP: Mechanically operated fuel pump which develops high pressure to force fuel out of injectors and into combustion chambers.

DIESELING: Condition in which engine continues to run after ignition key is turned off. Also called "running on."

DIFFERENTIAL: Unit that will drive both rear axles at same time but will allow them to turn at different speeds in turns.

DIFFERENTIAL CASE (Carrier): Steel unit to which the ring gear is attached. Case drives spider gears and forms an inner bearing surface for axle end gears.

DIFFERENTIAL WINDING: A secondary winding in an electrical device that is wound in a reverse manner as related to the primary (main) windings.

DIMMER SWITCH: Foot or hand operated switch for headlight low and high beams.

DIODE: Unit having ability to pass electric current readily in one direction but resisting current flow in the other.

DIPSTICK: Metal rod that passes into oil sump. Used to determine quantity of oil in engine.

DIRECT CURRENT (DC): Electric current that flows steadily in one direction only.

DIRECT DRIVE: Such as high gear when crankshaft and drive shaft revolve at same speed.

DIRECT FUEL INJECTION: Fuel is sprayed into combustion chamber.

DIRECTIONAL STABILITY (Steering): Ability of car to move forward in straight line with minimum of driver control.

DIRT WEAR: (Antifriction bearing): Bearing wear caused by abrasive action of dirt.

DISCHARGE (Battery): Drawing electric current from battery.

DISCHARGE PRESSURE (Air conditioning): Pressure of refrigerant as it leaves compressor.

DISCHARGE SIDE (Air conditioning): The high pressure section of the air conditioning system extending from the compressor to the expansion valve.

DISC WHEEL: Wheel constructed of stamped steel.

DISPLACEMENT: Volume of air displaced by piston traveling from BDC to TDC.

DISTILLATION: Heating a liquid and then catching and condensing the vapors given off by heating process.

DISTILLED WATER: Water from which all impurities have been removed through an evaporative process.

DISTORTION: Altering shape or size of something through application of heat, pressure, motion, etc.

DISTRIBUTION BLOCK (Tubing): A multiple outlet tubing (pipe) fitting that is connected to an air, gas, water, etc., supply line so as to provide outlet connections for two or more branch lines.

DISTRIBUTION TUBES (Cooling system): Tubes used in engine cooling area to guide and direct flow of coolant to vital areas.

DISTRIBUTOR (Ignition): Unit designed to make and break the ignition primary circuit and to distribute resultant high voltage to proper cylinder at correct time.

DISTRIBUTOR CAP (Ignition): Insulated cap containing central terminal with series (one per cylinder) of terminals that are evenly spaced in circular pattern around central terminal. Secondary voltage travels to central terminal where it is then channeled to one of outer terminals by the rotor.

DIVERTER VALVE: A device used in the air injection system to divert air away from the injection nozzles during periods of deceleration. Prevents "backfiring."

DOHC: Refers to an engine with double (two) overhead camshaft.

DOT: Department of Transportation.

DOUBLE COMPRESSION FITTING: A tubing fitting in which, upon tightening, nose of the nut is forced tightly against tubing by a corresponding angle on fitting body. This provides seal.

DOUBLE FLARE: End of tubing, especially brake tubing, has a flare so made that flare area utilizes two wall thicknesses. This makes a much stronger joint and from safety standpoint, it is a must.

DOUBLE POST LIFT: Vehicle lift utilizing two lifting rams. Can be of suspension type (front and back ram) or frame type (side to side rams) design.

DOWEL PIN: Steel pin, passed through or partly through, two parts to provide proper alignment.

DOWNDRAFT CARBURETOR: A carburetor in which air passes downward through carburetor into intake manifold.

DOWNSHIFT: Shifting to lower gear.

DOWNSHIFT SWITCH: A switch that actuates an electrical solenoid that causes automatic transmission to downshift when throttle valve reaches a predetermined angle.

DRAG LINK: A steel rod connecting pitman arm to one of steering knuckles. On some installations drag link connects pitman arm to a center idler arm.

DRAIN COCK: A faucet-like fitting used to drain water, fuel, etc., from engine, radiator, fuel tank, etc.

DRAIN PLUG: A plug that can be removed to drain oil pan, differential, transmission, etc.

DRAW (Electrical): Amount of electrical current required to operate electrical device.

DRAW (Forming): To form (such as wire) by pulling wire stock through series of hardened dies.

DRAW (Temper): Process of removing hardness from a piece of metal.

DRAW-FILING: Passing file, at right angles, up and down length of work.

DRIER (Receiver-drier): Tank, containing desiccant, inserted in air conditioning system to absorb and retain moisture.

DRILL: Tool used to bore holes.

DRILL GAUGE: A flat metal gauge used to check twist drill lip angle and width. Useful for accurate sharpening.

DRILL PRESS: Nonportable machine used for drilling.

DRIVE AXLE: A steel shaft used to transmit driving force (torque) from differential to driving wheels. May be of single or multiple piece construction.

DRIVE-FIT: Fit between two parts when they must be literally driven together.

DRIVELINE: Propeller shaft, universal joints, etc., connecting transmission output shaft to axle pinion gear shaft.

DRIVE OR PROPELLER SHAFT SAFETY STRAP: A metal strap or straps, surrounding drive shaft to prevent shaft from falling to ground in event of a universal joint or shaft failure.

DRIVE PATTERN (Gear teeth): Contact area between driving and driven gear tooth under driving (engine driving car) conditions — as opposed to coast (car driving engine) conditions.

DRIVE RATIO: Numerical ratio indicated by number of turns a driving gear must revolve to turn driven gear one full revolution. For example, if differential pinion must turn four times to turn ring gear once, differential ratio is 4 to 1.

DRIVE SHAFT: Shaft connecting transmission output shaft to differential pinion shaft.

DRIVE TRAIN: All parts that generate power (engine) and transmit it to road wheels (transmission, clutch, drive shaft, differential, drive axles).

DRIVING LIGHTS: Auxiliary headlights, often very bright, that can be used to increase amount of illumination provided by regular headlights.

DROP CENTER RIM: Center section of rim being lower than two outer edges. This allows bead of tire to be pushed into low area on one side while the other side is pulled over and off the flange.

DROP FORGED: Part that has been formed by heating steel blank red hot and pounding it into shape with a powerful drop hammer.

DROPPED AXLE: Front axle altered so as to lower the frame of car. Consists of bending axle downward at outer ends. (Solid front axle.)

DRY AIR: Compressed air that does not contain water in form of unsuspended droplets.

DRY CELL or DRY BATTERY: Battery (like flashlight battery) that uses no liquid electrolyte.

DRY CHARGED BATTERY: Battery with plates charged but lacking electrolyte. To be placed in service, electrolyte is added.

DRY DISC CLUTCH: A clutch design in which clutch disc friction surface operates without lubrication of any type.

DRY FRICTION: Resistance to movement between two unlubricated surfaces.

"DRY" SETTING (Carburetor): A carburetor float level setting (adjustment for fuel level) made without fuel being in fuel bowl.

DRY SLEEVE: Cylinder sleeve application in which sleeve is supported in block metal over its entire length. Coolant does not touch sleeve itself.

DRY SUMP: Instead of letting oil throw-off drain into a regular oil pan sump, system collects and pumps this oil to a remote (separate) container or sump.

DRY WEIGHT: Weight of vehicle without fluid (oil, fuel, water) in various units.

DUAL BRAKES: Tandem or dual master cylinder to provide separate brake system for both front and rear of car.

DUAL BREAKER POINTS (Ignition): Distributor using two sets of breaker points to increase cam angle so that at high engine speeds, sufficient spark will be produced to fire plugs.

DUALS: Two sets of exhaust pipes and mufflers — one for each bank of cylinders.

DUMMY SHAFT: A temporary shaft that is inserted through bearings, bushings, parts, etc., to hold them in proper alignment while regular shaft is inserted.

DUST BOOT: A flexible cloth, rubber, neoprene, etc., cover over a joint, connector, etc., to prevent entry of water or dirt into the unit.

DWELL: See Cam Angle.

DYE PENETRANT (Crack detection): A special penetrating dye used in crack detection. Dye flows into even tiny, invisible cracks. When surface is cleaned and developer applied, dye is drawn from cracks and spreads over surface far enough to make crack area very visible.

DYNAMIC BALANCE: When centerline of weight mass of a revolving object is in same plane as centerline of object, that object would be in dynamic balance. For example, weight mass of the tire must be in the same plane as centerline of wheel.

DYNAMO: Another word for generator.

DYNAMOMETER: Machine used to measure engine horsepower output. Engine dynamometer measures horsepower at crankshaft and chassis dynamometer measures horsepower output at wheels.

DYNAMOMETER BREAK-IN: Running a new or rebuilt engine, for a specific length of time, while engine is attached to a dynamometer. This permits controlled loading and careful monitoring of engine performance to insure proper break-in.

E

EARLY FUEL EVAPORATION (EFE): System that passes hot exhaust gases over a certain portion of intake manifold to provide better fuel atomization during engine warm-up.

EARTH (Electrical): British term for ground.

EARTH WIRE: British term for ground wire.

ECCENTRIC (Off center): Two circles, one within the other, neither sharing the same center. A protrusion on a shaft that rubs against or is connected to another part.

ECCENTRIC GRINDING (Brakes): Grinding contact surface of brake lining to a different contour (smaller radius) than that of brake drum. When applied, center of shoe contacts before ends. Additional braking pressure springs shoe so that entire lining surface contacts drum.

ECONOMIZER VALVE: Fuel flow control device within carburetor.

EEC: Evaporative Emission Control.

EGR: Exhaust Gas Recirculation.

ELASTICITY: That property of a material that allows it to stretch, compress, bend, without breaking and still return to its original size and shape. Rubber possesses great elasticity.

ELASTIC LIMIT: A measurement of how far material can be bent, stretched, compressed, etc., and still return to exact size, position, etc., when disturbing force is removed.

ELBOW (Pipe): A curved pipe fitting designed to produce a change in line direction. Common angles are 90 and 45.

ELECTRICAL CONDUCTIVE RESIDUE: Any material left following a process, such as soldering, in which residue itself can form a path for electrical current.

ELECTRICAL PITTING (Bearing): Erosion of a bearing surface caused by a flow of electricity through a revolving bearing. Tiny electrical arcs between moving parts burn pinholes in bearing surface.

ELECTRIC ARC: A flow of electricity across an air gap between two conductors. When voltage is high enough, air becomes ionized and then will conduct electrical current.

ELECTRIC ASSIST CHOKE: A choke utilizing an electric heating unit to speed up its opening time.

ELECTRIC FUEL PUMP: Fuel pump operated by electricity and electric motor. Normally mounted in or near fuel tank.

ELECTROCHEMICAL: Chemical (battery) production of electricity.

ELECTRODE (Spark plug): Center rod passing through insulator forms one electrode. The rod welded to shell forms another. They are referred to as center and side electrodes.

ELECTRODE (Welding): Metal rod used in arc welding.

ELECTRODE HOLDER (Arc welding): In arc welding, handle device that grasps welding electrode.

ELECTROLYTE: Sulphuric acid and water solution in battery.

ELECTROMAGNET: Magnet produced by placing coil of wire around steel or iron bar. When current flows through coil, bar becomes magnetized and will remain so as long as current continues to flow.

ELECTROMAGNETIC: Magnetic (generator) production of electricity.

ELECTRON: Negatively charged particle that makes up part of the atom.

ELECTRON THEORY: Accepted theory that electricity is flow of electrons from one area to another.

ELECTRONIC: Refers to electrical circuits or units employing transistors, magnetic amplifiers, computers, etc.

ELECTRONIC CONTROL: Using an electronic device, such as a computer, to operate or control action of some part or system.

ELECTRONIC CONTROL UNIT (ECU): A group of electronic components such as transistors, diodes, thermistors, resistors, etc., that are wired into a unified circuit in such a manner to produce specific electrical signals in response to external sensor inputs.

ELECTRONIC FUEL INJECTION: An electric solenoid type injector, engine sensors, computer, etc., used to control fuel spray into engine.

ELECTRONIC IGNITION: Ignition system with no conventional breaker points. Primary circuit is broken by magnetic pickup and electronic control unit.

ELECTRONIC LEAK DETECTOR (Air conditioning): An electrically operated instrument used to test air conditioning system for R-12 leakage.

ELECTROPLATE: Process of depositing gold, silver, chrome, nickel, etc., upon an object by placing object in special solution and then passing an electric current through solution. Object forms one terminal, special electrode the other. Direct current is used.

ELEMENT (Battery): Group of plates. Three elements for a six volt and six elements for a twelve volt battery. The elements are connected in series.

ELLIOT TYPE AXLE: Solid bar front axle on which ends span or straddle steering knuckle.

ELONGATE: Lengthening or stretching a material by application of some force such as heat, pressure, motion, etc.

EMERGENCY DRIVE LOCKOUT (4-wheel drive): A device, as employed on some full-time four-wheel drive vehicles, used to lock up transfer case differential so as to provide direct mechanical torque transfer to both front and rear drive differentials.

EMF: Electromotive force. (Voltage.)

EMISSIONS: By-products of automotive engine combustion that are discharged into atmosphere. Major pollutants are oxides of nitrogen, carbon monoxide, hydrocarbons, and various particulates. Term also includes vapor (hydrocarbon) loss from fuel tank and carburetor.

END LIFT: A lifting device designed to elevate one end of vehicle.

END PLAY: Amount of axial (lengthwise) movement between two parts.

ENERGY (Physics): Capacity for doing work.

ENGINE (Auto): Device that converts heat energy into useful mechanical motion.

ENGINE ADAPTER: Unit that allows a different engine to be installed in a car — and still bolt up to original transmission.

ENGINE BLOCK: Main engine casting that contains cylinders, piston and crankshaft assemblies. Head bolts to top. Oil sump or pan bolts to bottom.

ENGINE CENTERLINE: A line, equidistant from top, bottom, and sides, running through engine in a direction parallel to crankshaft.

ENGINE DISPLACEMENT (Size): Volume of space through which head of piston moves in full length of its stroke — multiplied by number of cylinders in engine. Result is given in cubic inches.

ENGINE MOUNTS: Pads made of metal and rubber which hold engine to frame.

ENGINE SEQUENCE TESTS: Laboratory engine tests to determine how well a specific engine oil will prevent scuffing, corrosion, oxidation, wear, etc. Also referred to as "Car Manufacturer's Sequence Tests."

ENGINE STAND: A holding fixture for engine so that disassembly, repair, etc., is made easier by having engine at standing height and capable of being turned to different positions.

EP LUBRICANT (Extreme pressure): Lubricant compounded to withstand very heavy loads imposed on gear teeth.

EPA: Environmental Protection Agency. This is a Federal agency.

EQUALIZER LINE (Air conditioning): On air conditioning systems employing a POA suction throttling valve, a tube connecting this valve to spot underneath expansion valve control diaphragm. This modulates expansion valve action.

ERMETO FITTING: A tubing fitting designed for high pressure application. A special compression sleeve cuts into tubing and forces it against body seat. Often used on heavy walled tubing that is hard to flare.

ESC: Electronic Spark Control.

ETCHING (Bearing): Dulling or corroding of bearing surface through action of water (rusting) or presence of a corrosive substance. Bearings that are inactive for prolonged periods are particularly susceptible.

ETHYL GASOLINE: Gasoline to which Ethyl fluid has been added to improve gasoline's resistance to knocking. Slows down burning rate thereby creating a smooth pressure curve that will allow the gasoline to be used in high compression engines.

ETHYLENE GLYCOL: Chemical solution added to cooling system to protect against freezing.

EVAPORATION: Process of a liquid turning into a vapor.

EVAPORATION CONTROL SYSTEM: Emission control system designed to prevent gasoline vapors from escaping into atmosphere from tank and carburetor.

EVAPORATOR: Unit in air conditioning system used to transform refrigerant from a liquid to a gas. It is at this point that cooling takes place.

EXCITE: To pass an electric current through a unit such as field coils in generator.

EXHAUST CUTOUT: Y-shaped device placed in exhaust pipe ahead of muffler. Driver may channel exhaust through muffler or out other leg of the Y where exhaust passes out without going through the muffler.

EXHAUST GAS ANALYZER: Instrument used to check exhaust gases to determine combustion efficiency.

EXHAUST GAS RECIRCULATION: Admitting a controlled amount of exhaust gas into intake manifold during certain periods of engine operation. This lowers combustion flame temperature, thus reducing level of nitrogen oxides emission.

EXHAUST MANIFOLD: Connecting pipes between exhaust ports and exhaust pipe.

EXHAUST PIPE: Pipe connecting exhaust manifold to muffler.

EXHAUST SENSOR: A device in exhaust stream to measure oxygen content. It can, through an electronic control unit, be used to alter air-fuel ratios, engine timing, etc.

EXHAUST STROKE: Portion of piston's movement devoted to expelling burned gases from cylinder.

EXHAUST SYSTEM: Parts which carry engine exhaust to rear of car — exhaust manifold, pipes, muffler, and catalytic converter.

EXHAUST VALVE (Engine): Valve through which burned fuel charge passes on its way from cylinder to exhaust manifold.

EXPANSION TANK: A tank, connected to cooling system, into which water can enter or leave as needed during coolant heating (expansion) or cooling (contraction).

EXPANSION VALVE (Air conditioning): Device used to reduce pressure and meter flow of refrigerant into evaporator.

EXTENSION HOUSING: A housing attached to rear of a transmission so as to render its length suitable to available space.

EXTENSION JACK: A lifting jack with a very long, adjustable stem making it suitable for supporting from floor to engine, transmission, etc., while vehicle is in air on a lift.

EYE BOLT: A bolt with threads on one end and a round loop (eye) on other. Useful for engine removal from car.

F

°F: Temperature measurement in degrees Fahrenheit.

FABRIC PLY (Tire): A layer of fabric (nylon, rayon, polyester, etc.) making up one of plies (layers) involved in construction of a tire. May refer to either sidewall or to tread plies.

FACE (Engine valve): That portion of intake or exhaust valve that contacts valve seat.

FACE INDENTED WEAR (Engine valve): A grooved wear area on valve face. Caused by wear and pounding action of valve face slamming against valve seat.

FACE SHIELD: A clear, protective shield that covers entire face for protection during grinding, striking, etc., operations.

FAHRENHEIT: Thermometer on which boiling point of water is 212 deg. and freezing point is 32 deg. above zero.

FAN: A device designed to create a moving stream of air. Generally employed for cooling purposes.

FARAD: Unit of capacitance; capacitance of condenser retaining one coulomb of charge with one volt difference of potential.

FAST CHARGING: Charging a battery by passing a relatively heavy current through it. This will restore battery charge reasonably well in one to two hours.

FAST IDLE: Engine idle rpm when throttle is held partially open by a fast idle cam or solenoid during cold engine idle conditions.

FEEDER WIRE: A wire supplying current to several circuits — such as the feeder wire to a terminal block to which several other circuit wires connect.

FEELER GAUGE: Thin strip of hardened steel, ground to an exact thickness, used to check clearances between parts.

FENDER COVER: A protective pad that is laid over car fender area to prevent marring paint while leaning over to work on underhood areas.

FENDER SKIRT: Plate designed to cover portion of rear fender wheel opening.

FERROMAGNETIC: That property of certain metals, such as steel, iron, nickel, etc., that cause it to form molecular alignment within magnetic domains when material is magnetized. A material that is magnetic, capable of being magnetized, or that responds to a magnetic field.

FERROUS METAL: Metal containing iron or steel.

F-HEAD ENGINE: Engine having one valve in the head and the other in the block.

FIBER GEAR: A gear constructed of resin impregnated fibers that are compressed and hardened. Generally provide quiet operation.

FIBERGLAS: Mixture of glass fibers and resin that when cured (hardened) produces a very light and strong material. Used to build boats, car bodies, repair damaged areas, etc.

FIELD: Area covered or filled with a magnetic force.

FIELD COIL: Insulated wire wrapped around an iron or steel core. When current flows through wire, strong magnetic force field is built up.

FIELD FRAME: That portion of an electrical generator or motor upon which field coil is wound.

FILAMENT: Fine wire inside light bulb that heats to incandescence when current passes through it. The filament produces the light.

FILLER METAL (Welding): Molten metal added to base metal during welding or brazing process.

FILLET: Rounding joint between two parts connected at an angle.

FILLET RADIUS: Degree of curve (radius) involved in a curved edge or corner such as used on crankshaft journals where journal end meets crankshaft sides. Fillet prevents corner cracking better than a sharp right angle corner. Indicates size of fillet.

FILLET WELD: A weld in which filler metal is placed in corner where two metal pieces join at angles to each other.

FILTER: Device designed to remove foreign substances from air, oil, gasoline, etc.

FINAL DRIVE RATIO: Overall gear reduction (includes transmission, overdrive, auxiliary transmission, etc., gear ratio as well as rear axle ratio) at rear wheels.

FINISHING STONE (Hone): Fine stone used for final finishing during honing.

FIRE WALL: Metal partition between driver's compartment and engine compartment.

FIRING ORDER: Order in which cylinders must be fired—1, 5, 3, 6, 2, 4, etc.

FIT: Contact area between two parts.

FIXED CALIPER (Brake): A disc brake design in which caliper body is rigidly attached and thus is unable to move in any direction. It cannot, as is done in a sliding caliper, center itself over disc or rotor.

FLAME ARRESTOR VENT PLUG (Battery): A battery filler plug designed to reduce possibility of an open flame igniting hydrogen gas present in battery cells. If gas hovering above battery is ignited, plug prevents flame from passing into battery.

FLANGE: A flared, collar-like section formed on a shaft, pipe, beam, etc. Often located on end to facilitate fastening sections together or to provide a base for affixing some other part.

FLANGED END AXLE: A drive axle with outer end formed into a flange to mount wheel.

FLANGE HEIGHT (Wheel): A distance determined by measuring from bottom of wheel bead to top of flange. Flange retains tire bead.

FLARE ANGLE (Tubing): The angle formed when end of tubing is spread (flared) open for use in a flare fitting.

FLARE CONNECTION: A tubing connection that both secures and seals by gripping flared end of tubing between two similar angled areas formed in fitting body and nut.

FLARING CONE: A tapered cone that is forced into open end of a piece of tubing to produce a flared end suitable for use in a flare fitting.

FLARING TOOL: Tool used to form flare connections on tubing.

FLASHBACK (Oxyacetylene welding): A condition in which oxygen has entered acetylene hose or vice versa and due to failure to correctly purge both lines, a combustible mixture exists in hoses. Upon lighting torch, flame, instead of burning just at tip, moves inside and a fire starts burning in hoses.

FLASHOVER (Electrical): A condition in which electrical current, instead of moving through an intended conductor, jumps across an open space or moves along surface of an insulator, such as a coil tower, distributor cap, etc., either directly to ground or to some other circuit.

FLASH POINT: The point in the temperature range at which a given oil will ignite and flash into flame.

FLAT HEAD: Engine with all the valves in block.

FLAT SPOT: Refers to a spot experienced during an acceleration period where the engine seems to "fall on its face" for a second or so and will then begin to pull again.

FLEXIBLE DRIVE PLATE (Automatic transmission): A thin, bendable drive plate attached both to crankshaft and transmission torque converter. Drives torque converter.

FLINT: Stone-like material that is used in a spark lighter for welding torches. The flint, when scratched across a rough, hardened metal surface, gives off a heavy shower of sparks.

FLOAT: Unit in carburetor bowl that floats on top of fuel. It controls inlet needle valve to produce proper fuel level in bowl, can be of hollow metal, plastic, or cork.

FLOAT BOWL: The part of the carburetor that acts as a reservoir for gasoline and in which the float is placed.

FLOAT CIRCUIT: That portion of the carburetor devoted to maintaining a constant level of fuel in carburetor. Consists of float bowl, float, inlet valve, etc.

FLOAT DROP: A measurement of distance a carburetor fuel bowl float moves from full up to full down positions (no fuel in bowl). Can also indicate a specified distance from a specific spot on float to a specific spot on carburetor, with float in full down position.

FLOATING CALIPER (Brakes): A disc brake in which caliper assembly is mounted on pins (rods) to allow some lateral (side) movement. This permits caliper to automatically maintain a centralized position over disc or rotor.

FLOATING INSERT (Bearing): A precision insert friction bearing that has bearing material on both inner and outer surfaces. Bearing slides against both journal and bore surfaces. It is seldom used.

FLOAT LEVEL: Height of fuel in carburetor float bowl. Also refers to specific float setting that will produce correct fuel level.

FLOODING: Condition where fuel mixture is overly rich or an excessive amount has reached cylinders. Starting will be difficult and sometimes impossible until condition is corrected.

FLOW METER: Sensing device which measures flow of air or liquid.

FLUID COUPLING: Unit that transfers engine torque to transmission input shaft through use of two vaned units (called a torus) operating very close together in a bath of oil.

FLUID DRIVE FAN: A cooling fan that uses a liquid, such as silicone oil, to permit a controlled amount of slippage to limit maximum fan speed. Also controls fan speed, through thermostatic valve action, in relation to engine temperature requirements.

FLUORESCENT PENETRANT: A crack detection solution that penetrates into even minute cracks. When surface is wiped clean, a developer will draw penetrant to surface where it will spread out wider than crack. When subjected to black light, penetrant glows, disclosing crack.

FLUTE: Groove in cutting tool that forms a passageway for exit of chips removed during the cutting process.

FLUX (Magnetic): Lines of magnetic force moving through magnetic field.

FLUX (Soldering, brazing): Ingredient placed on metal being soldered or brazed, to remove and prevent formation of surface oxidation which would make soldering or brazing difficult.

FLUX CORE WIRE SOLDER: Wire solder with a hollow center that is filled with either rosin or acid flux.

FLYWHEEL: Relatively large wheel that is attached to crankshaft to smooth out firing impulses. It provides inertia to keep crankshaft turning smoothly during periods when no power is being applied.

It also forms a base for starter ring gear and in many instances, for clutch assembly.

FLYWHEEL RING GEAR: Gear on outer circumference of flywheel. Starter drive gear engages ring gear and cranks engine.

FLYWHEEL RUNOUT: Measured amount of either side to side (lateral) movement or radial (up and down) movement present in a revolving flywheel.

FOG LIGHTS: Amber or clear lamps specially designed to provide better visibility in fog. Are usually mounted as close to the road as is feasible.

FOOT POUND: Measurement of work involved in lifting one pound one foot.

FOOT POUND (Tightening): One pound pull one foot from center of an object.

FORCE: Pressure (pull, push, etc.) acting upon body that tends to change state of motion, or rest, of the body.

FORCE-FIT: Same as drive-fit.

FOREHAND WELDING: An oxyacetylene welding technique in which torch tip is aimed slightly away from molten puddle and towards direction of welding.

FORGE: To force piece of hot metal into desired shape by hammering.

FOUR BANGER, SIX BANGER, ETC.: Four cylinder, six cylinder engine, etc.

FOUR BOLT MAIN: A crankshaft main bearing employing two fasteners on each side.

FOUR-ON-THE-FLOOR: Four-speed manual transmission with floor mounted shift.

FOUR-STROKE CYCLE ENGINE: Engine requiring two complete revolutions of crankshaft to fire each piston once.

FOUR-WHEEL DRIVE: Vehicle, such as Jeep, in which front wheels, as well as rear, may be driven.

FRACTIONAL DRILL: A twist drill, size of which is indicated in fractions (1/16, 1/8, 3/16, etc.) of an inch.

FRAME: Portion of automobile upon which body rests and to which engine and springs are attached. Generally constructed of steel channels.

FRAME (Conventional): Strong, steel members run from front to rear of body.

FRAME (Integral): Car body serves as portion or all of frame.

FRAME RAILS: Structural sections of the car frame. Often specifically used to refer to two outside longitudinal sections.

FREE ELECTRONS: Electrons in outer orbits around nucleus of atom. They can be moved out of orbit comparatively easy.

FREE PLAY: Amount of unimpeded movement, radial, lateral, longitudinal, etc., that exists between two parts.

FREEWHEEL: Usually refers to action of car on downgrade when overdrive overrunning clutch is slipping with resultant loss of engine braking. This condition will only occur after overdrive unit is engaged but before balk ring has activated planetary gearset.

FREEZING: When two parts that are rubbing together heat up and force lubricant out of area, they will gall and finally freeze or stick together.

FREON-12: Gas used as cooling medium in air conditioning and refrigeration systems.

FREQUENCY: Rate of change in direction, oscillation, cycles, etc., in given time span.

FRETTING (Bearing): Corrosive-like surface damage to bearing face or to outer ring, outer surface or inner ring, inner surface. These are portions of bearing touching bore walls and shaft surface. There is little, or in some cases, no movement between these surfaces.

FRICTION: Resistance to movement between any two objects when placed in contact with each other. Friction is not constant but depends on type of surface, pressure holding two objects together, etc.

FRICTION BEARING: Bearing made of babbitt, bronze, etc. There are no moving parts and shaft that rests in bearing merely rubs against friction material in bearing.

FTC: Federal Trade Commission.

FUEL: Combustible substance that is burned within (internal) or without (external) an engine so as to impart motion to pistons, vanes, etc.

FUEL ACCUMULATOR: Spring loaded diaphragm device which dampens fuel pressure pulsations, muffles noise, and helps maintain residual pressure with engine off.

FUEL BOWL: Storage area in carburetor for extra fuel.

FUEL DISTRIBUTOR: Device which meters fuel to injectors at correct rate of flow for engine conditions.

FUEL FILTER: A device that removes dirt, rust particles, and in some cases, water from fuel before it moves into carburetor or fuel injection system.

FUEL GAUGE: A device to indicate the approximate amount of fuel in tank.

FUEL INJECTION: Fuel system that uses no carburetor but sprays fuel either directly into cylinders or into intake manifold just ahead of cylinders.

FUEL LEVEL (Carburetor): Normal working level or height of fuel in carburetor fuel bowl. Level is determined by float setting.

FUEL LEVEL "WET" SETTING: Checking or adjusting carburetor fuel level by measuring actual working height of gasoline in fuel bowl. When checking wet setting, be careful of fire!

FUEL LINE: That portion of the fuel system, consisting of tubing and hose, that carries fuel from tank to carburetor or injection system.

FUEL MIXTURE: Mixture of gasoline and air. An average mixture, by weight, would contain 16 parts of air to one part of gasoline.

FUEL PULSATION: Fuel pressure variations due to fuel pump action.

FUEL PUMP: Vacuum device, operated either mechanically or electrically, that is used to draw gasoline from tank and force it into carburetor.

FUEL PUMP PRESSURE: Pressure, in pounds per square inch or kilopascals, developed by a fuel pump.

FUEL PUMP VACUUM: Amount of vacuum, in inches of mercury, developed by a fuel pump.

FUEL PUMP VOLUME: Amount of fuel a pump will deliver in a specified period of time, at a specified rpm (where engine driven).

FUEL RAIL: In an electronic gasoline injection system, hollow pipe that is connected to and supplies fuel for injectors. Can also refer to a common feeder pipe for multi-carburetor installation.

FUEL TANK: A large tank of steel or plastic, used to store a supply of fuel aboard vehicle.

FULCRUM: Support on which a lever pivots in raising an object.

FULL-FLOATING AXLE: Rear drive axle that does not hold wheel on nor does it hold wheel in line or support any weight. It merely drives wheel. Used primarily on trucks.

FULL-FLOATING PISTON PIN: A piston pin that is free to turn in both piston and rod. Pin is secured by snap rings at each end.

FULL-FLOW LUBRICATION SYSTEM: An engine lubrication system in which all engine oil from oil pump must first pass through a filter before reaching bearings. If filter clogs, a bypass permits oil to reach bearings.

FULL-FLOW OIL FILTER: Oil filter that filters ALL of oil passing through engine—before it reaches the bearings.

FULL HOUSE: Engine that is fully modified and equipped for all-out performance.

FULL PRESSURE SYSTEM: Type of oiling or lubrication system using an oil pump to draw oil out of a sump and force it through passages in engine.

FULL REBOUND (Suspension): In a suspension system, position of a spring or shock at precise time that frame (or body) is separated from axles (or control arms) the maximum distance.

FULL-TIME FOUR -WHEEL DRIVE: Setup in which all four wheels are driven—all the time—off road or on. Addition of a third differential, located at transfer case, permits front and rear wheels to operate at different speeds.

FULL-TIME TRANSFER CASE: Four-wheel drive transfer case that drives all four wheels all the time. Two-wheel drive is not possible. Such systems permit four-wheel drive on dry, hard surfaced roads by incorporating a differential in transfer case unit.

FUSE: Protective device that will break flow of current when current draw exceeds capacity of fuse.

FUSE BLOCK: A central block or area for various circuit fuses.

FUSIBLE LINK: A special wire inserted into a circuit to provide protection in event of overloading, shorts, etc. Overloads will melt wire and break circuit. Unlike a regular fuse, fusible link will permit overloading for a short time before melting.

FUSION: Two metals reaching the melting point and flowing or welding themselves together.

G

GAL: Gallon.

GALLED (Bearing): Bearing surface damage caused by lack of lubrication, overheating, improper lubrication, etc. Metal surface in numerous high spots literally melts from heat and attempts to weld together, thus pulling out and smearing small chunks of metal. Advanced galling will cause bearing seizure.

GALVANOMETER: Instrument used to measure pressure, amount of, and direction of an electric current.

GAP BRIDGING (Spark plug): A buildup of carbon, lead, etc., on spark plug electrodes. Buildup can advance to point gap is completely filled (bridged) and plug becomes inoperative.

GAS: A nonsolid material. It can be compressed. When heated, it will expand and when cooled, it will contract. (Such as air.)

GAS BURNER or GASSER: Competition car with engine set up to operate on standard pump gasoline instead of an alcohol, nitro, etc., mixture.

GASEOUS SHIELD (Welding): Shield of inert gases produced when arc welding with coated electrodes or T.I.G., M.I.G., etc., welding setup. Gases shield molten metal being welded from air, thus preventing oxidization of weld metal.

GASKET: Material placed between two parts to insure proper sealing.

GASKET — MULTIPLE LAYER: A gasket utilizing two or more layers of different material, such as asbestos center, steel top and bottom.

GASKET — NEOPRENE: A gasket constructed of manufactured rubber. Impervious to most automotive oils, greases, solvents.

GASKET SHELLAC: A shellac sealing compound placed on certain gasket installations to assist in sealing and often, as an aid in positioning gasket during part assembly.

GASOHOL: Automotive engine fuel made up of around 90 percent gasoline and 10 percent ethanol alcohol.

GASOLINE: Hydrocarbon fuel used in the internal combustion engine.

GASSING: Small hydrogen bubbles rising to top of battery electrolyte during battery charging.

GAWR: See Gross Axle Weight Rating.

GEAR: Circular object, usually flat edged or cone-shaped, upon which a series of teeth have been cut. These are meshed with teeth of another gear and when one turns, it also drives the other.

GEAR BACKLASH: Amount of measured movement between mating gear teeth when one gear is held and other is moved to limit of travel, first one way then, then the other.

GEAR PUMP: A pump, utilizing two meshed gears, that draw in and force out oil, fuel, etc. Capable of building high pressure.

GEAR RATIO: Relationship between number of turns made by driving gear to complete one full turn of driven gear. If driving gear turns four times to turn driven gear once, gear ratio would be 4 to 1.

GEAR RUNOUT: A measured amount of either gear lateral movement (side to side wobble) or radial (up and down) movement that exists when a gear is revolved.

GENERATOR: Electromagnetic device for producing electricity.

GENERATOR REGULATOR: See Regulator.

GLASS: Term used for the material "Fiberglass."

GLASS PACK MUFFLER: Straight through (no baffles) muffler utilizing Fiberglas packing around perforated pipe to deaden exhaust sound.

GLAZE: Highly smooth, glassy finish on cylinder walls.

GLAZE BREAKER or DEGLAZER: Abrasive tool used to remove glaze from cylinder walls prior to installation of new piston rings.

GLAZED SURFACE (Cylinder): A cylinder surface that has worn to a bright, glass-like finish. This glaze must be removed by honing to insure proper seating of new piston rings.

GLOW PLUG: A heating device placed in a diesel engine precombustion chamber to facilitate cold engine starting. When engine is cold, an electric current is passed through plug causing it to glow red hot. This helps ignite compressed fuel.

GMC: General Motors Corporation.

GOVERNOR: Device designed to automatically control speed or position of some part.

GPM: Gallons Per Minute.

GRADIENT: Angle of hill. A 20 percent gradient would be a hill that would rise two feet for every ten forward feet of travel. This is determined by rise as a percentage of forward travel.

GRID: Lead screen or plate to which battery plate active material is affixed.

GRIND: Remove metal from object by means of revolving abrasive wheel, disc, or belt.

GROMMET: A rubber, plastic, etc., doughnut shaped object, with a slot cut around outer edge. Used to snap into holes in sheet metal to provide protection for a wire, tube, etc., passing through hole.

GROSS AXLE WEIGHT RATING: Total load carrying capacity of a given axle (front or back) setup. Weight rating can be expressed as rating at springs (total load on springs) or at ground (total load measured where tire meets ground). Weight at ground rating includes weight of tires, wheels, axle, and springs.

GROUND (Battery): Terminal of battery connected to metal framework of car. In this country, NEGATIVE terminal is grounded.

GROUND CLAMP (Welding): Clamp on end of ground wire. Must be attached to work to complete a circuit when arc welding.

GROWLER: Instrument used in testing starter and generator armature.

GUDGEON PIN: British term for piston or wrist pin.

GUM (Fuel system): Oxidized portions of fuel that forms deposits in fuel system or engine parts.

GUSSET: A metal piece, usually of flat plate, used to strengthen a joint between two parts such as frame rails. Usually welded or riveted into place.

GUT: To strip the interior of car. May also refer to removing internal baffles from muffler.

GVW: Gross Vehicle Weight. Total weight of vehicle including vehicle passengers, load, etc. Used as indicator of how heavy vehicle can be loaded (GVW minus vehicle curb weight equals payload).

GVWR: Gross Vehicle Weight Rating. See GVW.

H

HACKSAW: Hand operated metal cutting saw. Can use various blade lengths and tooth configurations.

HALF-HARD COPPER (Tubing): Copper tubing that has not been fully annealed (softened).

HALF-MOON KEY: Driving key serving same purpose as regular key but it is shaped somewhat like a half circle.

HALIDE TORCH: A gas torch used to detect R-12 leaks in air conditioning system.

HALOGEN BULB: Light bulb in which tungsten filament is surrounded by a halogen gas such as iodine, bromine, etc. Bulb glass is quartz to withstand intense heat.

HAND BRAKE: Hand operated brake which prevents vehicle movement while parked by applying rear wheel brakes or transmission brake.

HAND DRILL: A drill, either manual or electric, that is held in hands to operate.

HARDENING SEALANT: A sealant material that upon full curing, becomes hard.

HARMONIC BALANCER: See Vibration Damper.

HC: Symbol for hydrocarbon.

HEADLIGHTS: Main driving lights used on front of vehicle.

HEAD MARKING (Bolt): Marks placed on a bolt, capscrew, etc., to indicate fastener grade (material strength).

HEAD MATING SURFACE (Block): That portion of engine cylinder block that mates (contacts) with cylinder head.

HEAD PRESSURE: See Discharge Pressure.

HEAT BAFFLE: A shield placed around or next to some pipe, hose, wire, etc., to protect it from a heat source such as an exhaust manifold.

HEAT CHECKING (Brake): Small surface cracks in brake drums or brake discs (rotors) caused from heat generated during braking.

HEAT CONTROL VALVE (Manifold): A valve in exhaust manifold that directs a portion of hot exhaust gases to a selected area of intake manifold to provide heat for improved cold engine operation. Controlled by vacuum motor or thermostatic spring. Also called "heat riser," "early fuel evaporation valve," etc.

HEAT CROSSOVER (V-type engine): Passage from one exhaust manifold up, over, and under carburetor and on to other manifold. Crossover provides heat to carburetor during engine warmup.

HEAT DISCOLORATION: Metal surface coloring that is caused by application of heat, either from friction or from an outside heat source.

HEAT ENGINE: Engine operated by heat energy released from burning fuel.

HEAT EXCHANGER: Device, such as radiator, either used to cool or heat by transferring heat from one object to another.

HEAT RANGE: (Spark plugs): Refers to operating temperature of given style plug. Plugs are made to operate at different temperatures depending upon thickness and length of porcelain insulator as measured from sealing ring down to tip.

HEAT RISER: Area, surrounding portion of the intake manifold, through which exhaust gases can pass to heat fuel mixture during warmup.

HEAT SINK: Device used to prevent overheating of electrical device by absorbing heat and transferring it to atmosphere.

HEAT STOVE: Sheet metal housing around a portion of exhaust manifold. An intake pipe from housing provides hot air to carburetor air cleaner when needed. Can also mean a small shrouded depression in exhaust manifold from which hot air may be drawn to automatic choke housing.

HEAT TRANSFER: Movement of heat from one object to another by convection, conduction, or radiation. Can also refer to movement of heat through a given object—by conduction.

HEAT TREATMENT (Metal): Application of controlled heat to metal object to alter its characteristics (toughness, hardness, etc.).

HEAVY REPAIR: Generally refers to shop work involving complete dismantling, rebuilding, replacement, etc., of major items such as engine, transmission, etc.

HEEL: (Brake): End of brake shoe which rests against anchor pin.

HEEL (Gear tooth): Wide end of tapered gear tooth such as found in differential gears.

Hg: Abbreviation for the word MERCURY. Vacuum is measured in inches of mercury.

HELICAL: Spiraling shape such as that made by a coil spring.

HELICAL GEAR: Gear that has teeth cut at an angle to centerline of gear.

HELI-COIL: A coil spring insert used to create new threads (same diameter and thread as original) in a hole with stripped threads.

HEMI: Engine using hemispherical-shaped (half of globe) combustion chambers.

HEMISPHERICAL COMBUSTION CHAMBER: A round, dome-shaped combustion chamber that is considered by many to be one of the finest shapes ever developed. Hemispherical-shape lends itself to use of large valves for improved breathing and suffers less heat loss than other shapes.

HERRINGBONE GEARS: Two helical gears operating together and so placed that angle of the teeth form a "V" shape.

HEX NIPPLE (Pipe): A pipe nipple with center section hexagonal (six sided) shape.

HIGH COMPRESSION HEADS: Cylinder head with smaller combustion chamber area thereby raising compression. Head can be custom built or can be a stock head milled (cut) down.

HIGH FLASH POINT: A liquid such as cleaning solution, oil, etc., that must be heated to fairly high temperatures before vapors will spontaneously ignite.

HIGH PRESSURE LUBRICANT: A lubricant containing special additives that provide great resistance to film rupture under heavy contact pressure, such as is found in some traction type differentials.

HIGH-PRESSURE SPRAY CLEANING: Cleaning process employing a solution under heavy pressure, that is discharged at high velocity from a spray nozzle.

HIGH RANGE (4-wheel drive): The upper gear (more road speed, less torque) of a two speed (high-low) transfer case as used in four-wheel drive applications.

HIGH REACH JACK: A lifting jack in which the lift arm, ram, etc., can move over a very long range making it capable of raising objects to a considerable height.

HIGH-RISE MANIFOLD: Intake manifold designed to mount carburetor or carburetors, considerably higher above engine than is done in standard manifold. Done to improve angle at which fuel is delivered.

HIGH SIDE (Air conditioning): In an air conditioning system, that portion of system that operates under considerable pressure (between compressor and expansion valve).

HIGH TENSION: High voltage from ignition coil. May also indicate secondary wire from the coil to distributor and wires from distributor to plugs.

HOIST: See Chain Hoist.

HOLD-DOWN CLIP: A metal or plastic device (clip) used to secure a wire, pipe, hose, etc., so as to prevent movement, vibration, etc.

HOLDING JIG: A device for holding an object while grinding, bending, machining, etc.

HOLE SAW: Metal cutting saw made in shape of a tube, one end has cutting teeth, other a drive tang. Used for cutting round holes in sheet metal, wood, etc.

HONE: To remove metal with fine grit abrasive stone to precise tolerances.

HONED TO SIZE: A bearing bore, bushing, etc., brought to final finished size by honing (removal of a small amount of metal with an abrasive material such as a stone).

HONING MACHINE: Machine used to bring bearing bores, bushings, etc., to accurate, smooth finished size, by removing a small amount of metal stock with abrasive stones.

HONING OIL: Special oil used in honing process. Flushes stones to assist in cutting and reduces heat buildup.

HOOD PINS: Pins designed to hold hood closed.

HOOKE'S LAW: Law stating that amount of distortion (bending, twisting, lengthening, etc.) caused in a solid, as long as it is kept within elastic limits of material, will be directly proportional to applied force.

HOOK RULE: Small, short (6 in.) flat steel rule with a hook attached to scale starting end.

HOPPING UP: Increasing engine performance through various modifications.

HORIZONTAL-OPPOSED ENGINE: Engine possessing two banks of cylinders that are placed flat or 180 deg. apart.

HORSEPOWER: Measurement of engine's ability to perform work. One horsepower is defined as ability to lift 33,000 pounds one foot in one minute. To find horsepower, total rate of work in foot pounds accomplished is divided by 33,000. If a machine was lifting 100 pounds 660 feet per minute, its total rate of work would be 66,000 foot pounds.

Dividing this by 33,000 foot pounds (1 horsepower) you find the the machine is rated as 2 horsepower (hp).

HORSEPOWER (Brake): See Brake Horsepower.

HORSEPOWER (Frictional): Amount of horsepower lost to engine friction.

HORSEPOWER (Gross): Maximum horsepower developed by engine without a fan, air cleaner, alternator, exhaust system, etc.

HORSEPOWER (Net): Maximum horsepower developed by engine equipped with fan, air conditioning, air cleaner, exhaust system, and all other systems and items normally present when engine is installed in car.

HORSEPOWER – WEIGHT FACTOR: Relationship between total weight of car and horsepower available. By dividing weight by horsepower, number of pounds to be moved by one horsepower is determined. This factor has a great effect on acceleration, gas mileage, and all around performance.

HOSE CLAMPS: Devices used to secure hoses to their fittings.

HOSES: Flexible rubber tubes for carrying water, oil, air, and other fluids.

HOTCHKISS DRIVE: Method of connecting transmission output shaft to differential pinion by using open drive shafts. Driving force of rear wheels is transmitted to frame through rear springs or through link arms connecting rear axle housing to frame.

HOT IDLE: Engine idle speed during normal operating temperature range. It is slower than that of "cold idle" (fast idle).

HOT PATCH (Tire): Application of a sealing patch to a tire or tube through use of heat and pressure.

HOT SPOT: Localized area in which temperature is considerably higher than surrounding area.

HOT TANK: Tank filled with a hot, caustic solution (often alkaline based). Used for heavy duty cleaning of radiators, engine blocks, etc.

HOT WIRE: Wiring around key switch so as to start car without key. Wire connected to battery or some part of electrical system in which a direct connection to battery is present. A current-carrying wire.

HOUSING SPREADER (Differential): A tool used to spread differential housing a small amount to permit removal or installation of differential case and bearing assembly.

Hp: Horsepower.

HUB (Wheel): Unit to which wheel is bolted.

HUNTING GEARSET (Differential): A ring and pinion gearset in which the same teeth on pinion and ring mesh every so many revolutions. Even ratios such as 3 to 1, 2.5 to 1, etc., bring this about. By using a ratio of 3.11 to 1, 2.53 to 1, etc., this would not occur and the gearset would then become "nonhunting."

HYATT ROLLER BEARING (Antifriction): Similar to conventional roller bearing except that rollers are hollow and are split in a spiral fashion from end to end.

HYDRAULIC: Refers to fluids in motion. Hydraulics is science of fluid in motion.

HYDRAULIC BRAKES: Brakes operated by hydraulic pressure. Master cylinder provides operating pressure transmitted via steel tubing to wheel cylinders or pistons that apply brake shoes to brake drums and/or discs.

HYDRAULIC FLOOR JACK: A low hydraulic jack, equipped with wheels for easy moving, used for lifting front, side, or rear of car.

HYDRAULIC HAND JACK: A compact, powerful, portable hydraulic jack consisting of base, reservoir, and short ram.

HYDRAULIC LIFTER: Valve lifter that utilizes hydraulic pressure from engine's oiling system to keep it in constant contact with both camshaft and valve stem. They automatically adjust to any variation in valve stem length.

HYDRAULIC PRESS: A press with a large, suspended hydraulic cylinder and ram. Ram is actuated by pressure generated in a small cylinder and transmitted through a connecting pipe to large cylinder. Used for applying force to remove or install bearings, collars, bushings, etc.

HYDRAULIC PULLER: A pulling device utilizing a hydraulic cylinder to generate force required.

HYDRAULICS: The science of liquid in motion.

HYDRO-BOOST: Name for one type of hydraulically operated (steering pump pressure) brake booster.

HYDROCARBON: A mixture of hydrogen and carbon.

HYDROCARBON—UNBURNED: Hydrocarbons that were not burned during the normal engine combustion process. Unburned hydrocarbons make up about 0.1 percent of engine exhaust emission.

HYDROCARBONS: Combustion of hydrogen and carbon atoms. All petroleum based fuels (gasoline, kerosene, etc.) consist of hydrocarbons.

HYDROMETER: Float device for determining specific gravity of electrolyte in a battery. This will determine the state of charge.

HYDROPNEUMATIC SUSPENSION: Suspension system using both a liquid (oil) and compressed air for springing.

HYGROSCOPIC: Ability to absorb moisture from air.

HYPOID GEARING: System of gearing wherein pinion gear meshes with ring gear below centerline of ring gear. This allows a somewhat lower drive line thus reducing hump in the floor of car. For this reason hypoid gearing is used in differential on many cars.

I

ICEI: Internal Combustion Engine Institute.

ICING: Formation of ice (under certain atmospheric conditions) on throttle plate, air horn walls, etc., caused by lowering of fuel mixture temperature as it passes through air horn.

ID: Inside diameter.

IDLE: Indicates engine operating at its normal slow speed with throttle closed.

IDLE MIXTURE: Air-fuel mixture delivered to engine during idle.

IDLER ARM: Steering system part that supports one end of center link.

IDLER GEAR: A gear, between two other gears, that is driven by one and drives other. This permits both driving and driven gear to rotate in same direction with no change in gear ratio.

IDLER SPROCKET: An additional sprocket, generally used on long runs of timing chain, that takes up excess chain slack to prevent harmful chain flap or distortion.

IDLE SCREW: (Carburetor): Adjusting screw (now fixed at factory) used to control amount of and/or ratio of fuel and air delivered to engine during idle.

IDLE SPEED SCREW: A screw used to adjust carburetor throttle plate position to secure desired idle rpm.

IDLE VALVE or IDLE NEEDLE: Needle used to control amount of fuel mixture reaching cylinders during idling. It, or they, may be adjusted by turning the exposed heads.

IGNITION: Lighting or igniting fuel charge by means of a spark (gas engine) or my heat of compression (diesel engine).

IGNITION SWITCH: Key operated switch in driver compartment for connecting and disconnecting power to ignition and electrical system.

IGNITION SYSTEM: Portion of car electrical system, designed to produce a spark within cylinders to ignite fuel charge. Consists basically of battery, key switch, resistor, coil, distributor, points, condenser, spark plugs, and necessary wiring.

IGNITION TIMING: Refers to relationship between exact time a plug is fired and position of piston in degrees of crankshaft rotation.

I-HEAD ENGINE: Engine having both valves in the head.

IHP: Indicated Horsepower.

IMEP: Indicated Mean Effective Pressure.

IMI: Ignition Manufacturer's Institute.

IMPACT SENSORS: An open switch used in a typical air bag system. The switch is designed to close when vehicle is involved in a severe frontal impact.

IMPACT WRENCH: An air or electrical driven wrench that tightens or loosens nuts, cap screws, etc., with series of sharp, rapid blows.

IMPELLER: Wheel-like device upon which fins are attached. It is whirled to pump water, move and slightly compress air, etc.

IN.: Inch.

INCH-GRAM: Metric unit of measure indicating amount of twisting or turning force being applied to something such as a fastener, shaft, etc.

INCH-OUNCES: English unit of measure indicating amount of twisting or turning force being applied to something such as a fastener, shaft, etc. Equivalent to one-twelfth inch-pound.

INCH-POUNDS: English unit of measure indicating amount of twisting or turning force being applied to something such as a fastener, shaft, etc. Equivalent to 12 inch-ounces.

INCLUDED ANGLE (Steering): Angle formed by centerlines drawn through steering axis (kingpin inclination) and center of wheel (camber angle) as viewed from front of car. Combines both steering axis and camber angles.

INDEPENDENT SUSPENSION: A suspension system that allows each wheel to move up and down without undue influence on other wheels.

INDICATED HORSEPOWER (ihp): Measure of power developed by burning fuel within cylinders.

INDIRECT FUEL INJECTION: Fuel is sprayed into intake manifold.

INDUCTION: Imparting of electricity into one object, not connected, to another by the influence of magnetic fields.

INERTIA: Force which tends to keep stationary object from being moved, and tends to keep moving objects in motion.

INERTIA SWITCH: An electrical switch designed to be operated by a sudden movement, such as that caused by a collision.

INFLATOR MODULE: Air bag system component that houses the inflatable bag, initiator, and gas generating material.

INHIBITED CLEANING SOLUTION: A caustic cleaning solution that has been weakened to prevent surface erosion of aluminum parts while soaking.

INHIBITOR: Substance added to oil, water, gas, etc., to prevent action such as foaming, rusting, etc.

INJECTOR: Refers to valve mechanism (used in fuel injection system) that squirts or injects measured amount of gasoline into intake manifold in vicinity of intake valve. In diesel engine, fuel is injected directly into combustion chamber.

INJECTOR PUMP (Diesel): A mechanical pump that forces diesel fuel, under high pressure, to and through injector nozzles. Pump provides proper injection timing.

INJECTOR TIMING (Diesel): Relationship between instant of fuel injection in any one cylinder, to position of piston in degrees of crankshaft rotation.

IN-LINE ENGINE: Engine in which all cylinders are arranged in straight row.

IN-LINE FUSE: A fuse placed directly in an individual circuit wire. Installed as close to electrical source as possible.

IN-LINE INJECTOR PUMP (Diesel): An injector pump utilizing a number of plungers operating in cylinders. Plunger-cylinder assemblies (one per engine cylinder) are positioned in a straight line and are operated by a single camshaft.

INNER FLAME CONE (Oxyacetylene): Small cone of flame visible at tip opening.

INPUT SHAFT: Shaft delivering power into mechanism. Shaft from clutch into transmission is transmission input shaft.

INSERT BEARING: Removable, precision made bearing which insures specified clearance between bearing and shaft.

INSERT RECESS CUTTER (Valve): A cutting tool used to counterbore head to install a valve seat insert. Removes integral seat and leaves a precise recess to accept insert.

INSERT REMOVAL PLUG (Valve): A tool used to grasp underside of a valve seat insert so that it may be pulled out.

INSIDE CALIPER: A precision measuring tool designed to measure inside diameter of cylinders, bearing bores, etc.

INSULATION: Material used to reduce transfer of noise (sound insulation), heat (heat insulation), electricity (electrical insulation).

INSULATOR (Electrical): Material that will not (readily) conduct electricity.

INTAKE MANIFOLD: Connecting tubes between base of carburetor and port openings to intake valves.

INTAKE STROKE: Portion of piston's movement devoted to drawing fuel mixture into engine cylinder.

INTAKE VALVE (Engine): Valve through which fuel mixture is admited to cylinder.

INTEGRAL: Part of. (The cam lobe is an integral part of camshaft.)

INTEGRAL CARRIER: A drive axle differential assembly in which carrier (supports differential case) is constructed as an integral part of housing and as such, cannot be removed as a separate unit.

INTEGRAL GUIDE (Valve): A valve guide machined right in head metal itself.

INTEGRAL SEAT (Valve): Valve seat cut right in head metal itself.

INTERFERENCE ANGLE (Valve): Approximate one degree difference in angle between valve face and valve seat, used to produce an interference fit.

INTERFERENCE FIT (Valve): A valve face-to-valve seat contact in which either valve face or valve seat is ground to a slightly different angle (around 1°) than other. Aids in quick seating.

INTERMEDIATE BEARING: A bearing on a multiple bearing shaft, such as camshaft, crankshaft, etc., that is located between two end bearings.

INTERMEDIATE GEAR: Any gear in auto transmission between 1st and high.

INTERMITTENT: Not constant but occurring at intervals.

INTERMITTENT FUEL INJECTION: Fuel system in which injectors are only open for short periods and remain closed rest of the time. Amount of fuel delivered is controlled by how long injector is held open.

INTERNAL COMBUSTION ENGINE: Engine that burns fuel within itself as means of developing power.

INTERNAL GEAR: A gear with teeth cut on an inward facing surface. Example: outer gear is a planetary gearset. Teeth face inward towards center.

INVERTED FLARE: A tubing 45° angle flare fitting in which nut (male threads) threads into body (female).

ION: Electrically charged atom or molecule produced by electrical field, high temperature, etc.

IONIZE: (Air): To convert wholly or partly, into ions. This causes air to become a conductor of electricity.

I.S.O. FLARE: A tubing flare that looks somewhat like a regular double-lap flare following initial belling operation. Belled end section is compressed between nut and body producing a secure seal.

J

JAB SAW: A special hacksaw used for cutting in restricted areas. Consists of a handle and rigid section to secure a short section of hacksaw blade.

JACKSHAFT: A shaft used between two other shafts.

JACK STAND: A fixed or adjustable height, metal stand placed under a raised vehicle. Prevents car from falling in event of jack failure or slippage.

JAM NUT: Two nuts securely tightened against each other on a stud. A wrench can then be placed on lower nut to remove stud or top nut to install. Can also be used to prevent a nut from loosening.

JET: Small hole or orifice used to control flow of gasoline or air in various parts of carburetor.

JOULE: Metre-kilogram-second (mks) unit of energy or work equal to a force of 1 newton applied through a distance of 1 metre. Joule is the equivalent of 0.737324 foot-pounds.

JOURNAL: Part of shaft prepared to accept a bearing. (Connecting rod, main bearing.)

JOURNAL POLISHING: Removing minute sharp edges following grinding of a camshaft, crankshaft, etc., bearing journal(s). Leaves extremely smooth finish (around 7 micro inches).

JOURNAL TAPER: Condition in which one end of a bearing journal is smaller in diameter than other. Difference in two readings indicates amount of taper.

JUMPER CABLES: Two large diameter (8 gauge or heavier) insulated cables with clamps. Used to temporarily connect a charged battery to a discharged one to provide extra cranking capacity. Use caution!

JUMPER WIRE: A length of automotive wire, used for bypassing a defective circuit, testing a bulb, etc.

JUMP STARTING: Starting a vehicle with a discharged battery by using jumper battery or vehicle with a charged battery. Batteries are connected with jumper cables. Connect in parallel. Follow safety rules!

JUNCTION BLOCK: A connection point (block) for a number of wires. Can also contain receptacles for fuses. Generally incorporates a nonconducting base for mounting.

K

KEEN-SERT: A hollow type plug with internal and external threads. Used to bring a threaded, stripped hole back to a usable condition, diameter, etc.

KERF: Name commonly given to the cut (slot) made with an oxyacetylene cutting torch.

KEROSENE: Flammable hydrocarbon oil produced from distiling petroleum. Uses include fuel, lamp oil, etc.

KEY: Parallel-sided piece inserted into groove cut part way into each of two parts, which prevents slippage between two parts.

KEYWAY: Slot cut in shaft, pulley hub, wheel hub, etc. Square key is placed in slot and engages a similar keyway in mating piece. Key prevents slippage between two parts.

KICKDOWN SWITCH: Electrical switch that will cause transmission, or overdrive unit, to shift down to lower gear. Often used to secure fast acceleration.

KILL SWITCH: Special switch designed to shut off ignition in case of emergency.

KILOMETRE: Metric measurement equivalent to 5/8 of mile.

KILOPASCALS (kPa): Metric equivalent to English psi (pounds per square inch).

KINGPIN: Hardened steel pin that is passed through the steering knuckle and axle end. The steering knuckle pivots about the kingpin.

KINGPIN or STEERING AXIS INCLINATION: Tipping the tops of the kingpins inward towards each other. This places the centerline of steering axis nearer centerline of tire-road contact area.

KNIFE FILE: A file which has a blade that tapers to a sharp edge on one side. End view resembles a "drawn out" triangle shape.

KNOCKING (Bearing): Noise created by part movement in a loose or worn bearing.

KNOCKING (Fuel): Condition, accompanied by audible noise, that occurs when gasoline in cylinders burns too quickly. Also referred to as detonation.

KNUCKLE: A part utilizing a hinge pin (kingpin, swivel pin) that allows one part to swivel around another part. An example is a steering knuckle.

KNURL: To roughen surface of piece of metal by pressing series of cross-hatched lines into the surface and thereby raising area between these lines.

L

LACQUER: (Paint): Fast drying automotive body paint.

LAMINATED: Something made up of many layers.

LAND: Metal separating a series of grooves.

LANDS (Ring): Piston metal between ring grooves.

LAP: One complete trip around race track or route laid out for racing.

LAP or LAPPING: To fit two surfaces together by coating them with abrasive and then rubbing them together.

LATENT HEAT: Amount of heat (Btu's) beyond boiling or melting point, required to change liquid to a gas, or a solid to a liquid.

LATENT HEAT OF EVAPORATION: Amount of heat (Btu's) required to change a liquid to a vapor state without elevating vapor temperature above that of the liquid.

LATERAL MOVEMENT: Side to side movement (wobble or runout) such as may be exhibited by side surface of a revolving flywheel, tire, pulley, etc. Movement is in a direction nearly parallel to centerline of the shaft, hub, spindle, etc., object is attached to.

LB.: Pound.

LEAD BURNING: Connecting two pieces of lead by melting edges together.

LEADED GASOLINE: Gasoline containing tetraethyl lead, an antiknock additive. It must not be used in vehicles with catalytic converters.

LEAD HAMMER: A striking tool using a head made of lead to prevent marring object being struck.

LEAF SPRING: Suspension spring made up of several pieces of flat spring steel. Varying numbers of leaves (individual pieces) are used depending on intended use. One car uses single leaf in each rear spring.

LEAN MIXTURE (Fuel): Mixture with an excessive amount of air in relation to fuel.

LEAKDOWN RATE: Rate at which a gas or fluid, under pressure, escapes from container. In an engine hydraulic valve lifter, how long it takes to collapse lifter a specified distance under a specified pressure.

LEFT-HAND THREAD: A thread that is cut so that fastener must be turned counterclockwise to tighten, clockwise to loosen.

LETTER DRILLS: Series of drills in which each drill size is designated by letter of alphabet—A, B, C, etc.

LEVER: A rigid bar or shaft pivoting about a fixed fulcrum (shaft, pin, etc.). It is used to increase force or to transmit or change motion.

LEVER BENDER (Tubing): A mechanical, hand operated tubing bender using a lever arm to form a smooth bend in tubing.

LEVERAGE: Increasing force by utilizing one or more levers.

L-HEAD ENGINE: Engine having both valves in block and on same side of cylinder.

LIFT SADDLE: That portion of a lift designed to engage vehicle frame, axle, etc., for lifting.

LIFT STRAP: A strap specifically designed for engine removal. Has an adjustable, non-slip pull point attachment.

LIGHTENED VALVES: Valves in which all possible metal has been ground away to reduce weight. This will allow higher rpm without valve float.

LIGHT REPAIR: Automotive repair work involving ignition, cooling, fuel, charging, electrical, etc., systems. Work in which parts are relatively small and easily portable.

LIMITED-SLIP DIFFERENTIAL: Differential unit designed to provide superior traction by transferring driving torque, when one wheel is spinning, to wheel that is not slipping.

LINE BORING: Boring a series of holes, bushings, etc., so that all are accurately aligned with a common centerline.

LINKAGE: Movable bars or links connecting one unit to another.

LIQUID CHARGING (Air conditioning): Charging (adding R-12) air conditioning system with liquid R-12 instead of R-12 vapor.

LIQUID LINE: (Air conditioning): High-pressure liquid refrigerant line between receiver-dehydrator and expansion valve.

LIQUID TRACTION: Special liquid applied to tires of drag racers to provide superior traction.

LIQUID-VAPOR SEPARATOR: Tank which prevents liquid fuel from entering vapor line.

LIQUID WITHDRAWAL (LPG): Drawing LPG from bottom of tank to insure delivery of liquid LPG. Withdrawal from top of tank will deliver LPG in the gaseous state.

LITRE: Metric measurement of capacity—equivalent to 2.11 pints. Five litres equals 1.32 gallon.

LIVE AXLE: Axle upon which wheels are firmly affixed. Axle drives the wheels.

LIVE WIRE: See Hot Wire.

LOAD RANGE (Tire): Letter system (A, B, C, etc.) used to indicate specific tire load and inflation limit.

LOBE: Projection (hump-like portion) of a cam, such as on engine camshaft, that extends beyond base circle.

LOCATING LUG (Bearing): A small projecting tab, lip, etc., on a precision insert bearing that holds it in place to prevent either insert rotation or end movement.

LOCKING PLATE: A metal plate, one section of which is affixed to part and other to a nut, capscrew, etc., to prevent fastener loosening.

"LOCK UP" TORQUE CONVERTER: A torque converter equipped with a hydraulically operated clutch that, when applied, locks impeller (pump) and turbine together, thus eliminating fluid slippage.

LOCKWASHER: A washer, either split or with locking tabs, placed between a fastener and part. When fastener is tightened, washer cuts into both fastener and part and prevents loosening.

LOCKWASHER – EXTERNAL: A thin, flat lockwasher with bent friction tabs around outer edge. Tabs prevent fastener loosening.

LOCKWASHER – INTERNAL: A thin, flat lockwasher with friction tabs around edge of hole. Tabs cut into fastener and part to prevent loosening.

LOG MANIFOLD: Special intake manifold generally designed to accept four or more carburetors. Each side has bases for carburetors set on a pipe-like log area.

LONG and SHORT ARM SUSPENSION: Suspension system utilizing upper and lower control arm. Upper arm is shorter than lower. This is done so as to allow wheel to deflect in a vertical direction with a minimum change in camber.

LONGITUDINAL LEAF SPRING: Leaf spring mounted parallel to length of car.

LOUVER: Ventilation slots such as sometimes found in hood of automobile.

LOW BRAKE PEDAL: Condition where brake pedal approaches too close to floorboard before actuating the brakes.

LOW FLASH POINT: That property of a liquid that will allow vapors given off during heating to ignite spontaneously at a relatively low liquid temperature.

LOW LEAD FUEL: Gasoline containing not much more than 0.5 grams of tetraethyl lead per gallon.

LOW PIVOT SWING AXLE: Rear axle setup that attaches differential housing to frame via a pivot mount. Conventional type of housing and axle extend from differential to one wheel. The other side of differential is connected to other driving wheel by a housing and axle that is pivoted at a point in line with differential to frame pivot point.

LOW PRESSURE ADAPTER (Lubrication): An adapter that is placed on a high pressure lube gun that reduces pressure to prevent universal joint seal and bearing retainer damage. Used on other low pressure applications also.

LOW PRESSURE LINE: (Air conditioning): Low pressure refrigerant line between evaporator outlet and compressor.

LOW PRESSURE SPRAY CLEANING: Part cleaning through use of an air stream that, passing through nozzle, draws in cleaning solution. Solution then leaves nozzle in form of a spray.

LOW RANGE (Transfer case): Lower gear range in a typical two-speed (high-low) four-wheel drive transfer case. Provides more torque and less road speed.

LOW SIDE (Air conditioning): That portion of an air conditioning system that is subjected to low pressure R-12. Extends from expansion valve (evaporator) to suction side of compressor.

LPG: Liquefied petroleum gas.

LUBRICANT: Any material, usually of a petroleum nature such as grease, oil, etc., that is placed between two moving parts in an effort to reduce friction.

LUBRICATION: Reducing friction between parts by coating them with oil, grease, etc.

LUBRICATION PASSAGE: A hole, channel, groove, etc., designed to permit flow of lubricant.

LUG (Engine): To cause engine to labor by failing to shift to a lower gear when necessary.

LUMEN: A measurement of light intensity.

M

MACHINE SCREW: A nontapered screw, using a standard screw thread. May utilize a round, flat, oval, fillister, hex, etc., head. Head may be formed to accept an Allen, Phillips, Fluted, Clutch, etc., wrench or driver.

MACPHERSON STRUT: Front end suspension system in which wheel assembly is attached to a long, telescopic strut. Strut permits wheels to pivot and move up and down. Strut also acts as a shock absorber.

MAG: Magneto.

MAGNAFLUX: Special chemical process used to check parts for cracks.

MAGNET (Permanent): Piece of magnetized steel that will attract all ferrous material. Permanent magnet does not need electricity to function and will retail its magnetism over a period of years.

MAGNETIC CLUTCH (Air conditioning): Electromagnetic clutch that engages or disengages air conditioning compressor pulley.

MAGNETIC FIELD: Area encompassed by magnetic lines of force surrounding either a bar magnet or electromagnet.

MAGNETIC PULSE DISTRIBUTOR: An electronic (no breaker points) distributor that makes and breaks coil primary circuit through means of a magnetic pickup assembly that is triggered by an armature (reluctor, trigger wheel) tooth passing close by. Induced current (pulse) triggers a transistor thus breaking the circuit.

MAGNETO: Engine driven unit that generates high voltage to fire spark plugs. It needs no outside source of power such as battery.

MAGS or MAG WHEEL: Lightweight, sporty wheels made of magnesium. Term mag is often applied to aluminum, and aluminum and steel combination wheels.

MAIN BEARING BORE: Cylindrical hole in which precision insert crankshaft main bearings are placed.

MAIN BEARING CAP: Removable section (cap) that contains lower half of crankshaft main bearing insert.

MAIN BEARINGS (Engine): Bearings supporting crankshaft in cylinder block.

MAIN BEARING SUPPORTS: Steel plate installed over main bearing caps to increase their strength for racing purposes.

MAIN DISCHARGE TUBE: Carburetor fuel passage from bowl to air horn.

MAIN JOURNAL GAUGE: A gauge designed to check crankshaft main bearing journals for size, taper, and out-of-roundness, while crank is still mounted in block.

MAJOR DIAMETER (Thread): Diameter of a fastener threaded area, as determined by distance from top of one thread, at right angles through center of fastener, to top of a corresponding thread.

MANDREL: Round shaft used to mount stone, cutter, saw, etc.

MANIFOLD: Pipe or number of pipes connecting series of holes or outlets to common opening. See Exhaust and Intake Manifold.

MANIFOLD ABSOLUTE PRESSURE SENSOR (MAP): A sensing device that detemines intake manifold pressure as a factor of engine speed and load changes. Sensor sends appropriate electrical signals to an electronic control module. Control module adjusts fuel injector pulse width accordingly.

MANIFOLD GAUGE SET (Air conditioning): A manifold assembly containing two pressure gauges (one high, one low), two gauge valves, and three outlet connections. Used to service (discharge, charge) air conditioning system.

MANIFOLD HEAT CONTROL VALVE: Valve placed in exhaust manifold, or in exhaust pipe, that deflects certain amount of hot gas around base of carburetor to aid in warmup.

MANOMETER: Instrument to measure pressure (vacuum).

MANUAL CHOKE: Carburetor choke operated by hand.

MANUAL CONTROL VALVE (Transmission): Hand (linkage) operated valve which controls oil flow and transmission gear selection.

MASTER CYLINDER: Part of hydraulic brake system in which pressure is generated.

MASTER ROD (Radial engine): Primary or main connecting rod to which other connecting rods are attached.

MATING SURFACE: A surface upon an object that is placed in contact with a surface on another object. Can also refer to a specific area being used as a contact surface.

MATTER: Substance making up physical things occupying space, having weight, and perceptible to the senses.

MAXIMUM WEAR: Generally refers to greatest amount of wear (cylinders, journals, etc.) that can be tolerated before part must either be rebuilt or replaced. Can also refer to a section of a cylinder, shaft, etc., that has greatest amount of wear.

MECHANICAL BRAKES: Service brakes that are actuated by mechanical linkage connecting brakes to brake pedal.

MECHANICAL EFFICIENCY: Engine's rating as to how much potential horsepower is wasted through friction within moving parts of engine.

MECHANICAL FUEL INJECTION: A mechanically driven pump forces fuel into engine.

MECHANICAL FUEL PUMP: Engine mounted pump operated by eccentric.

MECHANICAL LIFTER (Valve): A nonhydraulic valve lifter. Does not self-adjust and requires a specific clearance (tappet clearance) that must be adjusted periodically.

MECHANICAL PULLER: A nonhydraulic pulling device utilizing either a screw thread, lever, or hammer blow as a means of developing pulling pressure.

MEGOHM: 1,000,000 ohms.

MELTING POINT: Temperature point at which a material changes from a solid into a liquid.

MEMA: Motor and Equipment Manufacturers' Association.

MEP: Mean Effective Pressure. Pressure of burning fuel (average) on power stroke subtracted by average pressure on other three strokes. Pressure is in pounds per square inch or kilopascals.

MESH: To engage teeth of one gear with those of another.

METAL FATIGUE: Crystallizing of metal due to vibration, twisting, bending, etc. Unit will eventually break. Bending a piece of wire back and forth to break it is a good example of metal fatigue.

METAL SHOT: Very small, metallic balls that are projected, by means of an air blast, against an object so as to remove rust, paint, etc. May also be used for light surface peening to relieve surface tension.

METERING ROD: Movable rod used to vary opening area through carburetor jet.

METERING VALVE (Brakes): Valve in brake line that limits fluid pressure to disc brakes. This assures that the rear (drum) brakes apply at about the same time as front (disc) brakes.

METRIC SIZE: Units made to metric system measurement.

METRIC SYSTEM: A decimal system of measurement based on metre (area, length, volume), litre (capacity), and gram (weight and mass).

MICA: Insulation material used between commutator segments in DC generators and starter motors.

MICRO: When the word "micro" precedes measurement units, such as watt, ampere, etc., it means one-millionth of that unit.

MICRO INCH: A linear measurement unit equivalent to one millionth of an inch. Often used in describing relative smoothness of a metal surface finish as measured in micro inches.

MICROFARAD: 1/1,000,000 farad.

MICROMETER (Inside and outside): Precision measuring tool that will give readings accurate to within fraction of one thousandth of an inch.

MICROMETER – ANVIL: That portion of a micrometer that is engaged by tip of spindle if micrometer is closed. It forms one area that is held in contact with work to be measured. Spindle tip forms other. Reading indicates distance between anvil and tip.

MICROMETER DEPTH GAUGE: A micrometer specially designed to measure hole, spline, slot, etc., depth

MICROMETER – INSIDE: A straight-line micrometer designed to measure inside diameter of cylinders, bores, etc.

MICROMETER INTERCHANGEABLE ANVIL: An anvil designed to be used on a micrometer that features measurement coverage exceeding normal 1 in. range. A single outside micrometer can be made to read objects from 0 to 6 in., for example, by merely inserting proper length anvil. Inside micrometers use interchangeable rods.

MICROMETER LOCKNUT: Locking nut used to secure a setting by preventing accidental turning of thimble during handling.

MICROMETER – MULTIPLE RANGE: A single micrometer used over a wide range of measurement by either using interchangeable anvils of different lengths (outside micrometer) or interchangeable rods (inside micrometer).

MICROMETER – OUTSIDE: A micrometer designed to read outside diameters of pistons, journals, pins, etc.

MICROMETER RACHET: A small ratcheting knob on end of micrometer thimble. Operator may use knob to tighten spindle on workpiece. Upon reaching a predetermined pressure (torque), knob ratchet will slip. Provides even thimble tensioning for each setting.

MICROMETER SLEEVE LONG LINE: Reference line drawn length of sleeve. Forms edge line for sleeve numbers and reference line for thimble marks.

MICROMETER SLEEVE NUMBERS: Division line numbers along sleeve long line. Numbers indicate each .100 in. of spindle travel – from .000 to 1.000 in.

MICROMETER SPINDLE (outside micrometer): Sliding rod portion that is moved either in or out by rotating thimble. Workpiece is positioned between anvil and spindle tip.

MICROMETER THIMBLE: Knurled handle portion of micrometer that is turned to adjust micrometer to workpiece.

MICROMETER VERNIER SCALE: An additional set of longitudinal scale lines drawn on sleeve. Used in conjunction with thimble edge marks, these vernier lines enable operator to make readings accurate to .0001 in. (one ten thousandth).

MIG: A metal inert gas welding procedure in which inert gas is used to shield weld metal from atmosphere.

MIKE: Either refers to micrometer or to using micrometer to measure an object.

MILL: Often used to refer to engine.

To remove metal through use of rotating toothed cutter.

MILL FILE: A general purpose single-cut, flat file available in different lengths and cuts.

MILLIMETRE: Metric measurement equivalent to .039370 of an inch.

MILLING MACHINE: Machine that uses variety of rotating cutter wheels to cut splines, gears, keyways, etc.

MINIATURE FUSE: A very compact, plug-in type fuse. Uses two prongs connected by a wire-like element designed to melt when circuit loading exceeds a specified level (amperage).

MINIMUM WEAR: Can be used to indicate a small amount of wear that leaves part in serviceable condition. Can also be used to indicate, for example, that portion of a shaft, bore, etc., showing least amount of dimensional change from wear.

MINOR DIAMETER (Thread): Diameter as determined by measuring from bottom of one thread "V", at right angles through the center of fastener, to bottom of "V" of the corresponding thread.

MISFIRE: Fuel charge in one or more engine cylinders which fails to fire or ignite at proper time.

MIXING HANDLE (Gas welding): Handle, of an oxyacetylene welding torch, that contains both an acetylene and an oxygen control valve. Valves adjust flow and mixing occurs in handle area.

MODULATOR (Transmission): Pressure control or adjusting valve used in hydraulic system of automatic transmission.

MOLD: Hollow unit into which molten metal is poured to form a casting.

MOLECULE: Smallest portion that matter may be divided into and still retain all properties of original matter.

MONOBLOCK: All cylinders cast as one unit.

MONOLITHIC SUBSTRATE (Catalytic converter): A ceramic honeycomb mass, surface areas of which can be treated with platinum, palladium, and rhodium. Used in one type of catalytic converter.

MOTOR: Electrically driven power unit (electric motor). Term is often incorrectly applied to internal combustion engine.

MOTOR (Generator): Attaching generator to battery in such a way it revolves like an electric motor.

MOUNTING BULLET (Seal): A thin, smooth, round nose cap placed over nose of a shaft so that it may be passed through a seal without damage to seal lip.

MOVABLE POLE SHOE STARTER: A starter (cranking motor) design with a movable pole shoe attached, through linkage, to starter drive pinion assembly. When starter is energized, magnetic field forces movable shoe to actuate linkage, thus engaging starter drive pinion.

MPH: Miles per hour.

MUFFLER (Air conditioning): Device which reduces pumping noise and vibration in system.

MUFFLER (Exhaust): Unit through which exhaust gases are passed to quiet sounds of running engine.

MULTIPLE DISC CLUTCH: Clutch utilizing several clutch discs in its construction.

MULTIPLE LINK CHAIN: Drive chain employing, in addition to outside links, additional inner links. Permits use of a wide chain for great strength and good wear characteristics.

MULTIPLE-PLY HOSE: A hose using two or more layers or reinforcing fabric.

MULTIPLE ROW BEARING: A bearing containing two or more rows of balls, rollers, or needles.

MULTI-VISCOSITY OILS: Oils meeting SAE requirements for both low temperature requirements of light oil and high temperature requirements of heavy oil. Example: (SAE 10W-30).

MUSHROOM VALVE LIFTER: A valve lifter in which bottom is wider (a collar-like section) than main body that rides in lifter guide. Mushroom lifter requires removal of camshaft to withdraw lifter.

MUTUAL INDUCTION: Creating voltage in one coil by altering current in another nearby coil.

MVMA: Motor Vehicle Manufacturers Association.

N

NADA: National Automobile Dealers' Association.

NATTS: National Association of Trade and Technical Schools.

NBFU: National Board of Fire Underwriters.

NC THREADS: National Coarse thread sizes.

NEEDLE BEARING (Antifriction): Roller type bearing in which rollers have very narrow diameter in relation to their length.

NEEDLE NOSE FITTING (Lubrication): A grease fitting, such as used in some universal joints, that requires use of a needle nose (thin, pointed) tip on grease gun.

NEEDLE VALVE: Valve with long, thin, tapered point that operates in small hole or jet. Hole size is changed by moving needle valve in or out.

NF THREADS: National Fine thread sizes.

NEGATIVE SPREAD (Bearing): A two-piece insert bearing with diameter across outside of parting edges slightly smaller than bearing bore diameter. When inserted in the cap, insert will touch bottom but sides at parting edges will have some clearance.

NEGATIVE TERMINAL: Terminal (such as on battery) from which current flows on its path to positive terminal.

NEOPRENE: Synthetic rubber. Highly resistant to oils, grease, ozone, etc.

NEUTRAL FLAME: An oxyacetylene flame in which proportion of acetylene and oxygen are such that flame is neither reducing (carburizing — excess acetylene) nor oxidizing (excess oxygen).

NEUTRALIZE: To stop or destroy some force or chemical action, such as by applying baking soda solution to stop action of battery acid.

NEUTRAL SAFETY SWITCH: A switch that opens (disconnects) starter circuit when transmission is in gear.

NEUTRON: Neutral charge particle forming part of an atom.

NEWTON-METRES: A unit of force, as used in metric system, to indicate torque.

NEWTON'S LAW: For every action there is an equal, an opposite reaction.

NHRA: National Hot Rod Association.

NHTSA: National Highway Traffic Safety Administration.

NIASE: National Institute for Automotive Service Excellence.

NITROGEN OXIDES: In combustion process, nitrogen from air combines with oxygen to form nitrogen oxides.

NLGI: National Lubricating Grease Institute.

NONFERROUS METALS: All metals containing no iron—except in very minute quantities.

NONFLAMMABLE: A substance that will not burn.

NONHARDENING SEALANT: A sealant, that when fully cured, remains in a soft, pliable state.

NONHUNTING GEARSET (Differential): A ring and pinion gearset in which same teeth on ring and pinion DO NOT mesh on a regular basis every so many revolutions. Brought about by using uneven ratios such as 3.21 to 1, 4.11 to 1, etc. Nonhunting feature improves wear characteristics.

NONREINFORCED HOSE: Hose that uses no wires, fabric, etc., to strengthen it.

NONSEPARABLE BEARING: An antifriction bearing that cannot be taken apart.

NON-SERVICEABLE: A part or device whose design and construction does not permit rebuilding. Can also be used to indicate a part of device that is no longer fit for use.

NONSERVO BRAKE: A brake design in which each shoe (primary and secondary) works independently and as such, neither one assists in application of other.

NORMALIZING REGULATOR: Process of operating charging system for a specified period of time to bring regulator up to normal operating temperature.

NORTH POLE (Magnet): Magnetic pole from which lines of force emanate; travel is from north to south pole.

NOx: See Oxides of Nitrogen.

NOZZLE: Opening through which fuel mixture is directed into carburetor air stream.

NSC: National Safety Council.

NUMBER DRILLS: Series of drills in which each size is designated by number (0-80).

NUT — CASTLE: A nut with slots out through a reduced size top section. Slots accept cotter pins. Looks like a "castle."

NUT — HEX: Six sided (hexagonal) nut.

NUT — PAL: Thin, stamped nut that is turned tightly against regular nut to prevent loosening.

NUT — SLOTTED: A hexagonal nut with slots cut through top section to accept cotter pins.

NUT — SPEED: A thin, flat spring steel nut used for rapid fastener installation where great strength is not required.

NUT — WING: A nut with two wing-like projections to permit turning with fingers. Also called "thumb nut."

NYLON: A synthetic thermoplastic made up of long-chain polymeric amide molecules.

O

OCTANE RATING: Rating that indicates a specific gasoline's ability to resist detonation.

OD: Outside diameter.

ODOMETER: Device used to measure and register number of miles traveled by car.

OEM: Original Equipment Manufacturer.

OFF-ROAD VEHICLE: Vehicle designed to operate in rough country (hills, sand, mud, etc.) without benefit of regular roads.

OFFSET DOWEL PIN: A locating steel dowel pin in which around one-half of cylindrical body is offset somewhat from other. Following insertion in, for example, the rear face of block, they can be turned either direction to correct clutch housing bore to crankshaft misalignment. Fasteners are then tightened.

OHM: Unit of measurement used to indicate amount of resistance to flow of electricity in a given circuit.

OHMMETER: Instrument used to measure amount of resistance in given unit or circuit. (In ohms.)

OHM'S LAW: Formula for calculating electrical values in a circuit.

OIL BAFFLE: A thin plate or diaphragm (often steel) arranged to restrict, direct, control, etc., oil movement from one area to another. Often used in oil pan sump to prevent oil slosh and pump starvation during engine steep angle operation.

OIL BATH AIR CLEANER: Air cleaner that utilizes a pool of oil to insure removal of impurities from air entering carburetor.

OIL BURNER: Engine that consumes an excessive quantity of oil.

OIL CLASSIFICATION – CA, CB, CC, CD: Classifications for oil designed for use in diesel engines. Many automotive diesel engines require oil marked with classification SF/CC, SF/CD. Follow manufacturers recommendations.

OIL CLASSIFICATION – SA: (Utility Gasoline and Diesel Engine Service.) Oil for applications under light load, moderate speed, highly favorable service. Contains few or no additives.

OIL CLASSIFICATION – SC: (Minimum Duty Gasoline Engine Service.) For mild operating conditions. Contains some additives.

OIL CLASSIFICATION – SC: (1964 Gasoline Engine Service.) For service such as that experienced by engines built from 1964-1967. Contains additives to retard low temperature deposits, rust, wear, corrosion, etc.

OIL CLASSIFICATION – SD: (1968 Gasoline Engine Warranty Maintenance Service.) For service such as needed for 1968 through 1970 light truck and car engines. Contains more additives than SC oil.

OIL CLASSIFICATION – SE: (1972 Gasoline Engine Warranty Maintenance.) Oil for 1972 through 1979 light truck and car engines. Contains more additives than SD.

OIL CLASSIFICATION – SF: (1980 Gasoline Engine Warranty Service.) Oil recommended for 1980 and later car and light truck engines. Provides excellent protection against wear, heat, deposits, etc. Can be used where SE, SD, or SC are recommended.

OIL CLEARANCE (Bearing): Amount of operating clearance (between bearing and journal) needed to provide proper lubricating oil circulation.

OIL – COMBINATION SPLASH and PRESSURE SYSTEM: Engine oiling system that uses both pressure and splash oiling to accomplish proper lubrication.

OIL CONTROL RING: (Piston): A piston ring designed to prevent excessive oil consumption by scraping excess oil from cylinder. Usually lower (furthest down in cylinder) ring or rings.

OIL COOLER: Device used to remove excess heat from engine and/or transmission oil. Can be air or water cooled design.

OIL DIPSTICK: See Dipstick.

OIL FILTER: Device used to strain oil in engine thus removing abrasive particles.

OIL – FULL PRESSURE SYSTEM: Engine oiling system that forces oil, under pressure, to moving parts of engine.

OIL GALLERY: Pipe or drilled passageway in engine used to carry engine oil from one area to another.

OIL GAUGE: A dash mounted device that indicates engine oil pressure in pounds per square inch (psi) or kilopascals (kPa). Can be of electrical or Bourdon tube design.

OIL NOZZLE: A short section of pipe or nozzle used to direct a stream of oil against some moving part such as timing chain, gear, etc.

OIL PAN: See Pan.

OIL PICKUP: Connects to oil pump and extends into bottom of oil pan. Oil is drawn through pickup into pump.

OILPROOF PAPER: A special paper used to wrap greased antifriction bearings for long term storage. Prevents leaching of lube from bearings.

OIL PUMP: Device used to force oil, under pressure, to various parts of the engine. It is driven by gear on camshaft.

OIL PUMPING: Condition wherein an excessive quantity of oil passes piston rings and is consumed in combustion chamber.

OIL RING: Normally bottom piston ring which scrapes excess oil off cylinder wall.

OIL SEAL: Device used to prevent oil leakage past certain area.

OIL SEAL – DOUBLE LIP: An oil seal employing two sealing lips for added control.

OIL SEAL – GARTER SPRING: Continuous spring that maintains seal lip pressure against shaft.

OIL SEAL – SINGLE LIP: An oil seal employing one seal lip.

OIL SLINGER: Device attached to revolving shaft so any oil passing that point will be thrown outward where it will return to point of origin.

OIL SOAKED (Clutch, brakes): A condition in which friction surfaces, as used in dry clutches, brake lining, etc., become contaminated with oil. Discard such linings!

OIL – SPLASH SYSTEM: Engine oiling system that depends on connecting rods to dip into oil troughs and splash oil to all moving parts.

OIL STRAINER (Engine): A fine wire mesh screen through which oil entering oil pump is drawn. It will remove larger particles of dirt or other abrasives.

OIL SUMP: That portion of oil pan that holds supply of engine oil.

ONE-WAY CLUTCH: Locks shaft in one direction and allows rotation in other.

OPEN CIRCUIT: Circuit in which a wire is broken or disconnected.

OPEN CIRCUIT VOLTAGE (Battery): Cell voltage when battery has no completed circuit across posts and is not receiving or delivering energy.

OPEN WINDINGS (Electrical): A winding circuit that has been broken, thus stopping current flow.

ORGANIC FLUX (Soldering): A soldering flux somewhat less corrosive than acid flux. Should NEVER be used for electrical connections – always use rosin or resin flux!

ORIFICE: A small hole or restricted opening used to control flow of gasoline, air, oil, etc.

ORIFICE TUBE EXPANSION VALVE (Air conditioning): A form of air conditioning system expansion valve that utilizes a fixed orifice (hole) to control flow rate of R-12 to evaporator. Compressor clutch is cycled on and off to start and stop R-12 flow.

O-RING: A round ring, often of neoprene, that is used as a seal.

O-RING CONNECTOR (Tubing): A tubing fitting that uses an O-ring to produce a seal between tubing and fitting.

OSCILLATING ACTION: Swinging action such as that in pendulum of a clock.

OSCILLATING PISTON PIN: A piston pin secured to rod and thus forced to oscillate (rotate back and forth) in piston.

OSCILLOSCOPE: Testing unit which projects visual reproduction of the ignition system spark action onto screen of cathode-ray tube.

OTTO CYCLE: Four-stroke cycle consisting of intake, compression, firing, and exhaust strokes.

OUT-OF-ROUND: A piston, shaft, journal, etc., in which diameter is greater in one direction than another, thus forming an egg shape.

OUTPUT SHAFT: Shaft delivering power from within mechanism. Shaft leaving transmission, attached to propeller shaft, is transmission output shaft.

OUTSIDE CALIPER: An instrument used to check outside diameter of an object. Caliper leg tips are carefully adjusted to workpiece then removed. Distance between tips is measured with a steel rule.

OUTSIDE DIAMETER: Diameter of a cylinder, circle, etc., as measured in a straight line from outside surface on one side, through center, to outside surface on other side.

OVERCENTER ADJUSTMENT (Steering gear): Adjustment between pitman shaft gear sector teeth and ball nut teeth in straight ahead (center) position. Adjustment made by testing torque required to turn wormshaft from one side of straight ahead position, through straight ahead position (overcenter) on other side.

OVERDRIVE: Unit utilizing planetary gearset so actuated as to turn drive shaft about one-third faster than transmission output shaft.

OVERDRIVE STAGES: Locked-out; direct, freewheeling; and overdrive.

OVERDRIVE TRANSMISSION: A transmission in which highest gear utilizes a ratio that drives output shaft faster than input, thus allowing reduced engine rpm.

OVERHEAD CAMSHAFT: Camshaft mounted above the head, driven by long timing chain or belt.

OVERHEAD VALVES: Valves located in head.

OVERHEATING: A condition in which any part, fluid, system, etc., has attained a temperature considered excessive.

OVERPLATE (Friction bearing): A very thin layer, such as a tin-lead mix, applied over another layer of different material on a precision insert bearing.

OVERRUNNING CLUTCH: Clutch mechanism that will drive in one direction only. If torque is removed or reversed, clutch slips.

OVERRUNNING CLUTCH STARTER DRIVE: Starter drive that is mechanically engaged. When engine starts, overrunning clutch operates until drive is mechanically disengaged.

OVERSIZE BORE (Engine cylinder): A cylinder that has been bored out to a size that is larger than normal. Requires appropriate oversize piston.

OVERSIZE PIN: A piston pin that is larger in diameter than one of standard size. Used to compensate for pin boss, rod, or bushing wear.

OVERSIZE VALVE STEM: An engine valve with a stem that is larger in diameter than one of standard size. Used to compensate for valve guide wear.

OVERSQUARE ENGINE: Engine in which bore diameter is larger than length of stroke.

OVERSTEER: Tendency for car, when negotiating a corner, to turn more sharply than driver intends.

OXIDATION: Surface of a material, such as steel, combining with oxygen in air, thus forming a very thin layer of oxide.

OXIDES OF NITROGEN (NOx): Undesirable exhaust emission, especially prevalent when combustion chamber flame temperatures are high.

OXIDIZE (Metal): Action where surface of object is combined with oxygen in air to produce rust, scale, etc.

OXIDIZING FLAME: Welding torch flame with an excess of oxygen. Free or unburned oxygen tends to burn molten metal.

OXYACETYLENE WELDING: Welding in which required heat is produced by a torch burning a mixture of oxygen and acetylene.

OXYGEN: Gas, used in welding, made up of colorless, tasteless, odorless, gaseous element oxygen found in atmosphere.

OXYGEN SENSOR (Emission control): A oxygen sensitive sensor placed in engine exhaust stream. Electrical signals, varying with oxygen content of exhaust, are sent from sensor to electronic control module. Using these signals, along with others, control unit can adjust carburetor air-fuel mix, ignition timing, etc.

P

PADS (Brake): Another term for disc brake "shoe and lining" assembly.

PALLADIUM: Rare metallic element (Pd) often used as a catalyst coating in catalytic converters.

PAN: Thin stamped cover bolted to bottom of crankcase, forms a sump for engine oil and keeps dirt, etc., from entering engine.

PANCAKE ENGINE: Engine in which cylinders are on a horizontal plane. This reduces overall height and enables them to be used in spots where vertical height is restricted.

PAPER AIR CLEANER: Air cleaner that makes use of special paper through which air to carburetor is drawn.

PARABOLIC REFLECTOR: A light reflector (concave mirror) that emits parallel light rays. Bulb filament must be located at focal point of parabola.

PARALLEL CIRCUIT: Electrical circuit with two or more resistance units so wired as to permit current to flow through both units at same time. Unlike series circuit, current in parallel circuit does not have to pass through one unit to reach the other.

PARALLELOGRAM STEERING LINKAGE: Steering system utilizing two short tie rods connected to steering arms and to a long center link. The link is supported on one end on an idler arm and the other end is attached directly to pitman arm. Arrangement forms a parallelogram shape.

PARKING BRAKE: Hand operated brake which prevents vehicle movement while parked by locking rear wheels, or transmission output shaft.

PARKING LIGHTS: Small lights on sides, front, and rear of vehicle. Usually red or amber color in rear and amber in front. Used so that vehicle will be more visible during dark hours. Lights are turned on whenever headlight switch is operated.

PARKING PAWL: A plunger or toothed segment that engages a notched gear to lock up (Prevent rotation) transmission output shaft when placed in "park." Prevents car from rolling when automatic transmission is in park.

PARTICULATES (Lead): Tiny particles of lead found in engine exhaust emissions when leaded fuel is used.

PARTING EDGE (Bearing): That edge or surface that forms a juncture (connecting line) between upper and lower halves of a friction bearing.

PARTING SURFACE: Surface forming a juncture (connecting point) between two parts. When two parts are disassembled, they will separate at parting surfaces.

PARTS WASHER: A device (spray, soak, etc.) used to clean parts.

PART-TIME FOUR-WHEEL DRIVE: A four-wheel drive system that can be operated in either a two-wheel or four-wheel drive mode. This setup cannot be operated in four-wheel drive on dry, hard surfaced roads.

PART-TIME TRANSFER CASE: Four-wheel drive transfer case that permits either four-wheel or two-wheel drive.

PASCAL'S LAW: "When pressure is exerted on confined liquid, it is transmitted undiminished."

PASTE STATE: That state in which a material, such as solder, is neither solid or liquid but is soft and plastic-like.

PAWL: Stud or pin that can be moved or pivoted into engagement with teeth cut on another part—such as parking pawl on automatic transmission that can be slid into contact with teeth on another part to lock rear wheels.

PAYLOAD: Amount of weight that may be carried by vehicle. Computed by subtracting vehicle curb weight from GVW.

PCV (Positive Crankcase Ventilation): System which prevents crankcase vapors from being discharged directly into atmosphere.

PEDAL "FREE TRAVEL": Distance that a fully released brake or clutch pedal can be readily depressed before linkage actuates either master cylinder or clutch release fingers. Free travel insures that brake or clutch is fully released.

PEDESTAL GRINDER: A grinder mounted atop a somewhat slender column to place grinder at a convenient working height.

PEEN: To flatten out end of a rivet, etc., by pounding with round end of a hammer.

PENETRATING OIL: Special oil used to free rusted parts so they can be removed.

PERIPHERY: Outside edge or circumference.

PERMANENT MAGNET: Magnet capable of retaining its magnetic properties over very long period of time.

PETROL: Gasoline.

PETROLEUM: Raw material from which gasoline, kerosene, lube oils, etc., are made. Consists of hydrogen and carbon.

PHILLIPS HEAD SCREW: Screw having a fairly deep cross slot instead of single slot as used in conventional screws.

PHOSGENE GAS: A very toxic (poisonous) gas. Can be formed when refrigerant R-12 is exposed to an open flame.

PHOSPHATE COATING: A thin coating of phosphate applied to surface of metal. Sometimes applied to camshafts to aid in proper break-in. Often applied to other metallic surfaces to prevent corrosion.

PHOSPHOR-BRONZE: Bearing material composed of tin, lead, and copper.

PHOTOCHEMICAL: Relates to branch of chemistry where radiant energy (sunlight) produces various chemical changes.

PHOTOCHEMICAL SMOG: Fog-like condition produced by sunlight acting upon hydrocarbon and carbon monoxide exhaust emissions in atmosphere.

PICKUP (Oil): Screened unit that either floats on, or is submerged in, engine oil sump oil. Oil for pump enters through pickup.

PICKUP (Vehicle): A light duty (1/2, 3/4, 1 ton) open bed truck.

PICKUP COIL: Device in electronic type distributor which senses engine speed (distributor rotation) and sends electrical pulses to control unit.

PIEZOELECTRIC IGNITION: System of ignition that employs use of small section of ceramic-like material. When this material is compressed, even a very tiny amount, it emits a high voltage that will fire plugs. This system does not need a coil, points, or condenser.

PILOT BEARING (Clutch): A small bearing (either antifriction or bushing type) located in center of flywheel or crankshaft end. Bearing aligns and supports flywheel end of clutch shaft (transmission input shaft).

PILOT OPERATED ABSOLUTE (POA): A modified form of a suction throttling valve. Used in air conditioning system to control evaporator pressure so as to allow low evaporator temperatures without freezing (icing).

PILOT SHAFT: Dummy shaft placed in a mechanism as a means of aligning parts. It is then removed and regular shaft installed.

PIN BOSS: That section of engine piston that aligns and supports piston (wrist) pin.

PIN FITTING: Process involved in honing piston or rod pin bores until a correct pin fit is attained.

PINGING: Metallic rattling sound produced by the engine during heavy acceleration when ignition timing is too far advanced for grade of fuel being burned.

PINION CARRIER: Part of rear axle assembly that supports and contains pinion gear shaft.

PINION (Gear): Small gear either driven by or driving a larger gear.

PINION FLANGE (Differential): Unit (flange) splined to outer end of differential pinion gear shaft. Used as an attaching point for propeller shaft universal joint.

PINION SHAFT (Differential): Shaft that supports, aligns, and drives differential pinion gear.

PIN KNOCK: Sound (sharp, double-knock) produced by excessively worn piston pins and/or bearings.

PIN PUNCH: A punch with a long, narrow, nontapered nose. Used to drive pins from their holes.

PINTLE: A round pin about which some part pivots.

PINTLE VALVE (EGR valve): Diaphragm controlled valve used to control flow of exhaust gas through exhaust gas recirculation valve.

PIPES: Exhaust system pipes.

PISTON: Round plug, open at one end, that slides up and down in cylinder. It is attached to connecting rod and when fuel charge is fired, will transfer force of explosion to connecting rod then to crankshaft.

PISTON BOSS: Built-up area around piston pin hole.

PISTON COLLAPSE: Reduction in diameter of piston skirt caused by heat and constant impact stresses.

PISTON DISPLACEMENT: Amount (volume) of air displaced by piston when moved through full length of its stroke.

PISTON EXPANSION: Increase in diameter of piston due to normal piston heating.

PISTON HEAD: Portion of piston above top ring.

PISTON LANDS: Portion of piston between ring grooves.

PISTON PIN or WRIST PIN: Steel pin that is passed through piston. Used as base upon which to fasten upper end of connecting rod. It is round and is usually hollow.

PISTON RING: Split ring installed in a groove in piston. Ring contacts sides of ring groove and also rubs against cylinder wall thus sealing space between piston and wall.

PISTON RING (Compression): Ring designed to seal burning fuel charge above piston. Generally there are two compression rings per piston and they are located in two top ring grooves.

PISTON RING (Oil control): Piston ring designed to scrape oil from cylinder wall. Ring is of such design as to allow oil to pass through ring and then through holes or slots in groove. In this way oil is returned to pan. There are many shapes and special designs used on oil control rings.

PISTON RING END GAP: Distance left between ends of the ring when installed in cylinder.

PISTON RING EXPANDER: See Ring Expander.

PISTON RING GROOVE: Slots or grooves cut in piston head to receive piston rings.

PISTON RING SIDE CLEARANCE: Space between sides of ring and ring lands.

PISTON SKIRT: Portion of piston below rings. (Some engines have an oil ring in skirt area.)

PISTON SKIRT EXPANDER: Spring device placed inside piston skirt to produce an outward pressure which increases diameter of skirt.

PISTON SKIRT EXPANDING: Enlarging diameter of piston skirt by inserting an expander, by knurling outer skirt surface, or by peening inside of piston.

PISTON SLAP: Slamming side to side (tipping) movement of piston when piston-to-cylinder clearance is excessive. Can produce a very audible hollow, clattering sound.

PISTON THRUST PRESSURE: Pressure applied to cylinder wall by one side of piston. During compression stroke, piston is thrust against one side of cylinder and during firing stroke, against other.

PITCH: (Thread): Distance from center of one screw thread to center of adjacent (next to) thread. Pitch determines number of threads per inch.

PITMAN ARM: Short lever arm splined to steering gear cross shaft. Pitman arm transmits steering force from cross shaft to steering linkage system.

PITMAN SHAFT: (Steering): Steering gearbox shaft upon which pitman arm is attached.

PITS: Area at a race track for fueling, tire changing, making mechanical repairs, etc.

PIT STOP: A stop at the pits by racer, for fuel, tires, repairs, etc.

PIVOT: Pin or shaft about which a part moves.

PLANET CARRIER: Part of a planetary gearset upon which planet gears are affixed. Planet gears are free to turn on hardened pins set into carrier.

PLANET GEARS: Gears in planetary gearset that are in mesh with both ring and sun gear. Referred to as planet gears in that they orbit or move around central or sun gear.

PLANETARY GEARSET: Gearing unit consisting of ring gear with internal teeth, sun or central pinion gear with external teeth, and series of planet gears that are meshed with both the ring and the sun gear.

PLASTIC RANGE: Temperature range over which a material, such as solder, remains in plastic state (soft, not liquid or solid).

PLASTIGAGE: A soft plastic, in wire form, used to measure bearing clearance.

PLATES (Battery): Thin sections of lead peroxide or porous lead. There are two kinds of plates—positive and negative. The plates are arranged in groups, in an alternate fashion, called elements. They are completely submerged in the electrolyte.

PLATINUM: Precious metal sometimes used in the construction of breaker points. It conducts well and is highly resistant to burning.

PLAY: Movement between two parts.

PLEXIGLAS: Trade name for an acrylic plastic, made by the Rhom and Haas Co.

PLIERS: A tool with two pincer-like handles pivoted together, with various shaped jaws. Used for cutting, grasping, bending, etc.

PLIERS — CHAIN NOSE: Pliers with short tapered jaws.

PLIERS — DIAGONAL: Pliers with full length cutting jaws. Used to cut wires, cotter pins, etc.

PLIERS — ELECTRICIAN: Pliers with jaws that provide a flat gripping surface on front area along with a short cutting section on one side. Widely used by electricians.

PLIERS — IGNITION: Very small pliers designed for use on ignition distributors.

PLIERS — NEEDLE NOSE: Pliers with rounded, long, thin, tapered jaws designed for use in close quarters.

PLIERS — RIB JOINT: Pliers with a series of interlocking ribs that allow pliers to be adjusted over a very wide working range.

PLIERS — SLIP JOINT: Pliers in which pivot pin can be moved (slipped) from one of two holes to other to provide two distinct working ranges (amount of jaw opening).

PLIERS — VISE GRIP: Pliers that can be adjusted so that when handles are squeezed together, a special overcenter arrangement allows jaws to exert extremely heavy pressure. Continued handle closing allows handles to move overcenter, thus locking themselves into position while maintaining pressure.

PLIES (Tire): Layers of rubber impregnated fabric that make up carcass or body of tire.

PLUG GAPPING: Adjusting side electrode on spark plug to provide proper air gap between it and the center electrode.

PLUG WELD: A welding technique in which one steel plate, containing one or more holes, is placed in contact with another. They then are joined by applying weld metal in holes, thus fusing both parts together.

PLY RATING (Tires): Indication of tire strength (load carrying capacity). Does not necessarily indicate actual number of plies. Two-ply four-ply rating tire would have load capacity of a four-ply tire of same size but would have only two actual plies.

P-METRIC (Tire): Tire size designation based on international standards. Example: P 155/80R13. P = passenger car use. 155 = section width in millimetres. 80 = height to width ratio. R = radial construction. 13 = wheel rim diameter in inches.

PNEUMATIC: Pertaining to air. Operated by air pressure.

POCKET TAPE: A flexible, retracting measuring tape, available in different lengths, designed to be carried in pocket.

POLARITY (Battery terminals): Indicates if the battery terminal (either one) is positive or negative (plus or minus) (+ or −).

POLARITY (Generator): Indicates if pole shoes are so magnetized as to make current flow in a direction compatible with direction of flow as set by battery.

POLARITY (Magnet): Indicates if end of a magnet is north or south pole (N or S).

POLARIZING (Generator): Process of sending quick surge of current through field windings of generator in direction that will cause pole shoes to assume correct polarity. This will insure that the generator will cause current to flow in same direction as normal.

POLE (Magnet): One end, either north or south, of a magnet.

POLE SHOES: Metal pieces about which field coil windings are placed. When current passes through windings, pole shoes become powerful magnets. Example: pole shoes in a generator or starter motor.

POLYETHYLENE: Thermoplastic resin. Used for its flexible, tough, oil resistant and insulation properties as wire insulation, tubing, etc.

PONY CAR: Small, sporty car along the lines of the Mustang, Firebird, Camaro, etc.

POPPET: A spring-loaded ball engaging one or more indentations. Used to hold one object in position in relation to another.

POPPET VALVE: Valve used to open and close valve port to engine cylinders.

PORCELAIN (Spark plug): Material used to insulate center electrode of spark plug. It is hard and resistant to damage by heat.

POROSITY: Small air or gas pockets, or voids, in metal.

POROUS BRONZE: A material made by compressing tiny particles of bonze, under extremely high pressure, until they form a rigid but porous (full of holes) mass. Useful as a filter, oil retaining bushing, etc.

PORT: Openings in engine cylinder blocks for exhaust and intake valves and water connections.

To smooth out, align, and somewhat enlarge intake passageway to the valves.

PORTABLE CRANE: A hydraulic, electric, or manual lifting device equipped with wheels to facilitate moving about.

PORTABLE STEAM CLEANER: A relatively small steam cleaner equipped with wheels for easy portability.

"PORTED" SPARK ADVANCE: A distributor vacuum advance unit connected to a hole or "port" located a specified distance above carburetor throttle valve when in closed position. As throttle is opened, port will be uncovered and vacuum applied to advance unit.

POSITIVE TERMINAL: Terminal (such as on battery), to which current flows.

POST (Battery): Round, tapered lead posts protruding above top of battery to which battery cables are attached.

POTENTIAL: An indication of amount of available energy.

POTENTIOMETER: Variable resistor with three connections. One connection (called wiper) slides along resistive unit. Can be used as a voltage divider.

POUR POINT: Lowest temperature at which fluid will flow under specified conditions.

POWER: Time rate at which energy is converted into work.

POWER BOOSTER (Brakes): Engine vacuum or power steering fluid operated device on fire wall which increases brake pedal force on master cylinder during stops.

POWER BRAKES: A brake system in which a vacuum or hydraulic booster is used to greatly multiply foot pressure to master cylinder.

POWER DRILL: An electric or pneumatic tool designed to hold and rotate twist drills. Can also be used for wire brushing, polishing, etc., operations with correct accessories.

POWER PLANT (Auto): The vehicle engine.

POWER STEERING: Steering system utilizing hydraulic pressure to increase the driver's turning effort. Pressure is utilized either in gearbox itself or in hydraulic cylinder attached to steering linkage.

POWER STEERING PUMP: Belt driven pump which produces pressure for power steering system.

POWER or FIRING STROKE: Portion of piston's movement that transmits power of burning fuel mixture to crankshaft.

POWERTRAIN CONTROL MODULE (PCM): Small computer that controls the operation of the cruise control system and governs transmission/transaxle shift points.

PPM (Parts-Per-Million): Term used in determining extent of pollution existing in given sample of air.

PRACTICAL EFFICIENCY: Amount of horsepower delivered to drive wheels.

PRECISION INSERT BEARING: Very accurately made replaceable type of bearing. It consists of an upper and lower shell. The shells are made of steel to which a friction type bearing material has been bonded. Connecting rod and main bearings are generally of precision insert type.

PREHEAT FLAME (Cutting torch): Ring of small flames emitted at tip of an oxyacetylene cutting torch. They are used to heat metal to a red heat so as to facilitate cutting with a central jet of oxygen.

PREHEATING: Application of some heat prior to later application of more heat. Cast iron is preheated to avoid cracking when welding process is started. A coil (ignition) is preheated prior to testing.

PREHEATING (Metal): Process of raising temperature of metal to specific level before starting subsequent operations such as welding, brazing, etc.

PREIGNITION: Fuel charge being ignited before proper time.

PRELOADING: Adjusting antifriction bearing so it is under mild pressure. This prevents bearing looseness under a driving stress.

PRELUBRICATOR (Engine): A pressurized, oil-filled tank used to force lubricating oil through engine lubrication system prior to actually starting engine. Lubes all bearings and prevents possible delay in pressure buildup following first starting of a rebuilt engine.

PRESS-FIT: Condition of fit (contact) between two parts that requires pressure to force parts together. Also referred to as drive or force fit.

PRESSURE BLEEDER: Device that forces brake fluid, under pressure, into master cylinder so that by opening bleeder screws at wheel cylinders, all air will be removed from brake system.

PRESSURE CAP: Special cap for radiator. It holds a predetermined amount of pressure on water in cooling system. This enables water to run hotter without boiling.

PRESSURE DIFFERENTIAL SWITCH: Hydraulic switch in brake system that operates brake warning light in dashboard.

PRESSURE PLATE (Clutch): Circular plate, driven by flywheel, that forces clutch disc friction surface tightly against flywheel. When clutch is disengaged, pressure plate releases clutch disc.

PRESSURE REGULATOR VALVE (Fuel system): A valve, used in some gasoline injection systems, that maintains a predetermined level or pressure on fuel passing to fuel injectors.

PRESSURE RELIEF VALVE: Valve designed to open at specific pressure. This will prevent pressures in system from exceeding certain limits.

PRESSURE TESTER (Cooling): A hand operated air pump used to pressurize cooling system to check for leaks. Can also be used to check pressure cap for proper opening pressure and sealing leaks.

PRESTART PRESSURIZATION (Engine): See "Prelubricator."

PRICK PUNCH: A sharp, pointed steel punch used to place a small dot-like mark on a part. Has a sharper point (less included angle) than a center punch.

PRIMARY CIRCUIT (Ignition system): Low voltage (6 or 12 volt) part of ignition system.

PRIMARY, FORWARD, or LEADING BRAKE SHOE: Brake shoe installed facing front of car. It will be a self-energizing shoe.

PRIMARY WINDING (Coil): Low voltage (6 or 12 volt) winding in ignition coil. The primary winding is heavy wire; secondary winding uses fine wire.

PRIMARY WIRES: Wiring which serves low voltage part of ignition system. Wiring from battery to switch, resistor, coil, distributor points.

PRINTED CIRCUIT: Electrical circuit made by connecting units with electrically conductive lines printed on a panel. This eliminates actual wire and task of connecting it.

PROBE: (Mechanical): A thin, long necked tool that is often expandable. Used to reach into relatively inaccessible areas. May utilize a magnet or movable fingers for part insertion or removal or a mirror for viewing blind areas.

PROGRESSIVE LINKAGE: Carburetor linkage designed to open throttle valves of multiple carburetors. It opens one to start and when certain opening point is reached, it will start to open others.

PRONY BRAKE: Device utilizing friction brake to measure horsepower output of engine.

PROPANE (LPG): Petroleum product, similar to and often mixed with butane, useful as engine fuel. May be referred to as LP-Gas.

PROPELLER SHAFT: Shaft connecting transmission output shaft to differential pinion shaft.

PROPORTIONING VALVE (Brakes): Valve in brake line which keeps rear wheels from locking up during rapid stops.

PROTON: Positive charge particle, part of atom.

PRUSSION BLUE: A deep blue pigment (dye) mixed with a grease-like carrier. By spreading a thin film on one part and then placing other part firmly in position, then removing, it is possible to check contact surfaces for high and low spots.

PSI: Pounds per square inch.

PTO: Power take off. A spot or place on transmission or transfer case from which an operating shaft from another unit (such as a winch) can be driven. Usually consists of a removable plate that exposes a drive gear.

PUDDLE: (Welding): Area of base metal that is brought to molten state by electric arc or by oxyacetylene flame. Where required, filler rod is melted into puddle.

PULLER BAR: A rigid steel bar to which puller arms or jaws are attached. Bar allows different positioning of jaws to provide wide range of adjustment.

PULLER STRAP (Engine): A length of cable or chain with attachment device at each end, used to pull (raise) engines.

PULL IT DOWN (Engine): Term often used in reference to dismantling and overhauling an engine.

PULL POINT (Engines): When lifting engines, that point, in relation to static balance, at which lifting hook is attached to puller strap or bar. Pull point must be secure and located to keep engine properly balanced and at correct angle while lifting.

PULSATION DAMPER: Device to smooth out fuel pulsations or surges from pump to carburetor.

PULSE AIR INJECTION: Emission control system which feeds air into exhaust gases by using pressure pulsations of exhaust system.

PULSE WIDTH: Often used to describe length of time a fuel injector is held open. Pulse being electric current applied to the injector winding and width being length of time current is allowed to flow. The wider the pulse, the more fuel delivered.

PUMP: A device designed to cause movement of water, fuel, air, etc., from one area to another.

PUMP DIAPHRAGM (Fuel pump): A thin layer of flexible material (often neoprene coated fabric) stretched over a sealed compartment containing an inlet and an outlet check valve. By flexing diaphragm up and down, a pumping action is obtained.

PUMPING THE GAS PEDAL: Forcing accelerator up and down in an endeavor to provide extra gasoline to cylinders. This is often cause of flooding.

PURGE: Removing impurities from system. See Bleeding.

PUSH ROD: Rod that connects valve lifter to rocker arm. Used on valve-in-head installations.

PUSH ROD RUNOUT (Valve train): A measurement of amount of bend present in push rod. By placing each end in a V-block and then rotating with a dial indicator contacting the center area, exact amount of runout is determined.

PUSH ROD SEAT (Valve train): That portion of both valve lifter and rocker arm engaged by their respective ends of push rod.

PYLON: Marker for controlling traffic.

Q

QUADRANT (Gearshift): A gear position indicator often using a shift lever actuated pointer. Can be marked PRND21 (3-speed), PRND321 (4-speed), etc.

QUADRA-TRAC: See Full Time Four-Wheel Drive.

QUENCHED (Flame): Flame front in combustion chamber being extinguished as it contacts colder cylinder walls. This sharply elevates hydrocarbon emissions.

QUENCHING: Dipping heated object into water, oil, or other substance, to quickly reduce temperature.

QUICKSILVER: Metal mercury. Often used in thermometers.

QUICK TAKE-UP MASTER CYLINDER: A brake master cylinder that supplies a large amount of fluid (under low pressure) during first part of brake application. This supplies extra fluid needed to quickly return no-drag type brake caliper pistons so pads engage disc (rotor).

R

RACE (Bearing): Inner or outer ring that provides a contact surface for balls or rollers in bearing.

RACE CAMSHAFT: Camshaft, other than stock, designed to improve performance by altering cam profile. Provides increased lift, faster opening and closing, earlier opening and later closing, etc. Race camshafts are available as semi-race or street grind, three-fourths race or full race. Grinds in between these general categories are also available.

RACING SLICK: Type of tire used in "drag racing" as well as "stock car" applications. Tread surface of tire is completely smooth, for maximum rubber contact with track surface.

RACK AND PINION GEARBOX (Steering): Steering gear utilizing pinion gear on end of steering shaft. Pinion engages long rack (bar with teeth along one edge). Rack is connected to steering arms via rods.

RACK PISTON (Steering): In recirculating ball type of power steering gear, large piston that rides on worm. One side of piston has a series of teeth (called rack) that engage pitman shaft sector gear teeth. When worm is turned, rack piston slides (does not rotate), thus rotating pitman shaft.

RADIAL (Direction): Line at right angles perpendicular) to shaft, cylinder, bearing, etc., centerline.

RADIAL COMPRESSOR: A small air conditioning compressor using reciprocating pistons working at right angles to shaft and spaced around shaft in radial fashion.

RADIAL ENGINE: Engine possessing various numbers of cylinders so arranged that they form circle around crankshaft centerline.

RADIAL LOADING (Bearing): A load (pressure) placed on a bearing in a direction that would be at right angles to shaft centerline.

RADIAL MOVEMENT: Up and down movement (runout) such as that exhibited by outer surface of a revolving tire, wheel, shaft, etc. Movement is at right angles to axis of rotation.

RADIAL PRESSURE: Pressure on an object applied at a right angle to its centerline.

RADIAL RUNOUT: Rotating shaft, wheel, pulley, etc., runout (up and down movement) as measured at a right angle to centerline of shaft, axle, etc.

RADIAL TIRE: Plies parallel and at right angle to tread, belts under tread area.

RADIATION: Transfer of heat from one object to another when hotter object sends out invisible rays or waves that, upon striking colder object, cause it to heat.

RADIATOR (Engine cooling): A device used to remove heat from engine coolant. It consists of a series of finned passageways. As coolant moves through passages, heat is conducted to fins where it transfers to a stream of air forced through fins.

RADIATOR CAP: Pressure cap that fits on radiator neck. It keeps coolant from boiling.

RADIUS: Distance (in a straight line) from center of a circle or circular motion, to a point on edge (circumference).

RADIUS RODS: Rods attached to axle and pivoted on frame. Used to keep axle at right angles to frame and yet permit an up and down motion.

RAIL: Dragster built around a relatively long pipe frame. Often the only body panels used are around the driver's cockpit area.

RAM (Hydraulic): A round steel shaft, one end attached to a piston operating in a sealed cylinder. Other end passes out of cylinder and is placed against workpiece. When hydraulic pressure is applied to piston, ram exerts pressure on workpiece. Used in hydraulic jacks, presses, etc.

RAM AIR: Air "scooped" up by an opening due to vehicle forward motion.

RAM INDUCTION: Using forward momentum of car to scoop air and force it into carburetor via a suitable passageway.

RAM INTAKE MANIFOLD: Intake manifold that has very long passageways that at certain speeds aid entrance of fuel mixture into cylinders.

RASP CUT FILE: A file utilizing rows of relatively large sharp, tooth-like projections. Used for woodwork, filing soft metals, such as solder, brass and aluminum.

RASTER PATTERN: On an oscilloscope, a display of all engine cylinders, one above other, with number one cylinder at bottom of screen.

RATCHET HANDLE: Socket wrench handle with a ratcheting head to allow short back and forth handle movement without disengaging socket from fastener. Can be set to drive in either direction.

RATED HORSEPOWER (Engine): Indication of horsepower load that may safely be placed upon engine for prolonged periods of time. This would be somewhat less than the engine maximum horsepower.

RATIO: Fixed relationship between things in number, quantity, or degree. For example, if fuel mixture contains one part of gas for fifteen parts of air, ratio would be 15 to 1.

RAWHIDE HAMMER: A striking tool with a head formed of rawhide (untanned animal hide). Used for lighter striking on objects that would be damaged by a regular steel hammer.

RAYON BRAID (Hose): A woven rayon reinforcing layer, either in hose or applied to outside.

REACTOR: See Stator.

REAM: To enlarge or smooth hole by using round cutting tool with fluted edges.

REAMED FINISH: A finished surface in a bore, bushing, etc., produced by a reamer.

REAMER: A cylindrical cutting tool with a series of longitudinal fluted cutting edges (fixed or adjustable). Used to enlarge, bring to size, or finish a bore, bushing, etc.

REAMER – NONADJUSTABLE: A reamer that is of a fixed size.

REAMER – SPIRAL FLUTE: A reamer in which longitudinal fluted cutting edges, instead of paralleling tool centerline, are spiraled (like stripes on a barber pole). Tends to produce smoother cutting with less chatter.

REAMER – STRAIGHT FLUTE: Reamer in which longitudinal fluted cutting edges are straight and are parallel to the reamer centerline.

REAR AXLE (Banjo type): Rear axle housing from which differential unit may be removed while housing remains in place on car. Housing is solid from side to side.

REAR AXLE HOUSING (Split type): Rear axle housing made up of several pieces and bolted together. Housing must be split apart to remove differential.

REBABBITTING: Process of casting a new babbitt liner in a bearing. Babbitt (mix of lead, tin, copper, etc.) is firmly bonded to bearing bore.

REBORE (Engine): To bore out engine cylinders to a larger size. New pistons will be required.

RECEIVER-DRIER: See Drier.

RECIPROCATING ACTION: Back-and-forth movement such as action of pistons.

RECIRCULATING BALL WORM AND

NUT: Very popular type of steering gear. It utilizes series of ball bearings that feed through and around and back through grooves in worn and nut.

RECTIFIER: Device used to change AC alternating current into DC (direct current).

RED LINE: Top recommended engine rpm. If a tachometer is used, it will have a mark (Red line) indicating maximum rpm.

REDUCING FLAME: Welding flame in which there is an excess of acetylene.

REDUCTION (Gear): A gear that increases torque by reducing rpm of a driven shaft in relation to that of driving shaft.

REFRIGERANT: Liquid used in refrigeration systems to remove heat from evaporator coils and carry it to condenser.

REFRIGERANT-12: Name applied to refrigerant generally used in automotive air conditioning systems.

REFRIGERANT OIL: Special oil which lubricates air conditioning compressor.

REFRIGERATION CYCLE: Series of events or actions that take place in air conditioning system as R-12 refrigerant moves through system.

REGROUND: Refers to a crankshaft, camshaft, etc., on which bearing journals have been resurfaced by grinding. Unless built up before grinding, reground journals will have a smaller diameter.

REGULATOR (Electrical): Device used to control voltage and current output.

REGULATOR (Gas or liquid): Device used to reduce and control pressure.

RELATIVE HUMIDITY: Actual amount of moisture in a given sample of air compared to total amount that sample could hold (at same temperature).

RELAY: Magnetically operated switch used to make and break flow of current in circuit. Also called "cutout, and circuit breaker."

RELIEF VALVE: A spring-loaded valve designed to open and relieve pressure when pressure exceeds certain limits.

RELIEVE: Removing, by grinding, small lip of metal between valve seat area and cylinder—and removing any other metal deemed necessary to improve flow of fuel mixture into cylinder. Porting is generally done at same time.

RELUCTOR: A component in electronic ignition system distributor. It is affixed to the distributor shaft and triggers magnetic pickup. This, in turn, triggers control unit which breaks coil primary circuit causing coil to "fire."

REMOTE CHOKE (Carburetor): A bimetallic choke device, usually set in a choke stove well, located some distance from carburetor. Linkage connects choke to carburetor choke valve.

REPLACEABLE GUIDE (Valve): An engine valve guide that can be removed and replaced with a new guide.

RESIDUAL MAGNETISM: Magnetism remaining in an object after removal of any magnetic field influence.

RESIDUAL TENSION: A pulling force or strain that remains constantly applied to some object even though other major forces have been removed.

RESISTANCE (Electrical): Measure of conductor's ability to retard flow of electricity.

RESISTANCE WIRE: A wire designed to provide a carefully calculated resistance to electrical current flow. Can be used to limit current flow and to reduce voltage.

RESISTOR: Device placed in circuit to lower voltage. It will also decrease flow of current.

RESISTOR SPARK PLUG: Spark plug containing resistor designed to shorten both capacitive and inductive phases of spark. This will suppress radio interference and lengthen electrode life.

RESONATOR: Small muffler-like device that is placed into exhaust system near end of tail pipe. Used to provide additional silencing of exhaust.

RESURFACING (Block, head): Process of grinding or planing the engine block to cylinder head contact surfaces. Done to eliminate warpage, physical damage, etc., and in some cases, to increase compression.

RETARD: (Ignition timing): To set the ignition timing so that spark occurs later or less degrees before TDC.

RETORQUE: Following initial torquing, a second torquing of fasteners to compensate for gasket crush between parts, loosening caused by vibration, etc.

REVERSE-ELLIOT TYPE AXLE: Solid bar front axle on which steering knuckles span or straddle axle ends.

REVERSE FLUSH: Cleaning cooling system by pumping a powerful cleaning agent through system in a direction opposite to that of normal flow.

REVERSE IDLER GEAR: Gear used in transmission to produce a reverse rotation of transmission output shaft.

REVERSE POLARITY (Welding): In arc welding, when electrode is connected to machine positive terminal, ground wire to negative terminal.

RHEOSTAT: A variable type resistor used to control current flow.

RHODIUM: A metallic element (Rh), sometimes employed as a catalyst in catalytic converters.

RIBBED BELT: A flexible, fabric reinforced belt that uses a series of longitudinal "V" shaped ribs that mesh with corresponding grooves in pulleys.

RICARDO PRINCIPLE: Arrangement in which portion of combustion chamber came in very close contact with piston head. Other portion, off to one side, contained more space. As the piston neared TDC on compression stroke, fuel mixture was squeezed tightly between piston and head thus causing mixture to squirt outward into larger area in very turbulent manner. This produced a superior mixture and allowed compression ratios to be raised without detonation.

RICH MIXTURE (Fuel): Mixture with an excessive amount of fuel in relation to air.

RIDING THE CLUTCH: Riding the clutch refers to driver resting a foot on clutch pedal while car is being driven.

RIFLE BRUSH: A cylindrical bronze, steel, etc., bristle brush as used in cleaning bore of a firearm or small holes in parts.

RIGHT ANGLE: An angle of 90 degrees (one quarter of a circle).

RIGID HONE: A honing tool in which stone holders, although capable of in and out adjustment, cannot spring inward, tip, or flex. Stones thus remain parallel at all times.

RIM: (Tire): The outer portion of a wheel upon which tire is mounted.

RING: (Chrome): Ring on which the outer edge has a thin layer of chrome plate.

RING: (Pinned): Steel pin, set into piston, is placed in space between ends of ring. Ring is thus kept from moving around in groove.

RING BREAK-IN: Wearing-in process involved following installation of new piston rings. Tiny ridges on both rings and cylinder wall quickly wear off producing a smooth and proper fit.

RING – COMPRESSION: Piston ring designed to seal against leakage past piston. compression rings are located above oil ring.

RING COMPRESSOR: A tool designed to force piston rings inward in their grooves so that piston and rings can be inserted into engine cylinder bore.

RING EXPANDER: Spring device placed under rings to hold them snugly against cylinder wall.

RING FLOAT: That situation in which piston rings are not fully pressed against cylinder wall. Caused by excessive cylinder bore taper. Ring is squeezed in at bore bottom and piston travels to top and before ring can fully expand, returns to bottom.

RING GAP: Distance between ends of piston ring when installed in cylinder.

RING GAP SPACING: Locating ring gaps equidistant around piston. By spacing them so they do not line up, gas leakage through gaps is reduced and vertical wear pattern in cylinder is avoided. Also applies to gaps in a single, multiple piece ring.

RING GEAR: Large gear attached to differential carrier or to outer gear in planetary gear setup.

RING GEAR CENTERLINE: A line that would, if drawn across face of gear, pass through exact center of gear.

RING GEAR RUNOUT: Measured amount of wobble (side to side movement) produced when a ring gear is rotated through one full turn.

RING GROOVE CLEANER: A scraping tool designed to remove carbon from piston ring grooves.

RING GROOVE GAUGE: A measuring device (gauge) used to check piston ring groove depth to insure depth is compatible with replacement rings.

RING GROOVE RECONDITIONING TOOL: A tool, hand or power driven, used to cut a piston ring groove to a wider size, thus removing tapered, battered sides. A thin spacer is then inserted into top of recut groove returning it to proper size.

RING GROOVES: Grooves cut into piston to accept rings.

RING GROOVE SPACER: A thin spacer ring that is inserted in a groove cut on top side of a piston ring groove. Ring takes place of battered material machined from damaged groove and produces a groove of proper shape and size.

RING JOB: Reconditioning cylinders and installing new rings.

RING – OIL CONTROL: A slotted piston ring, often of multiple piece construction, used to prevent excessive oil flow past piston into combustion chamber. Scrapes oil from cylinder wall and returns it to crankcase.

RING RIDGE: Portion of cylinder above top limit of ring travel. In a worn cylinder, this area is of smaller diameter than remainder of cylinder and will leave ledge or ridge that must be removed.

RING RIDGE REAMER: A tool used to cut away narrow band of unworn cylinder wall (ring ridge) found between top of cylinder and highest point of ring travel.

RING SIDE CLEARANCE: That space existing between the side of piston ring and groove in which it operates.

RING – TAPER FACE: A piston ring on which ring face (side towards piston) is tapered when at rest, only a portion on ring face contacts wall.

RING TIPPING: A condition in which a piston ring operating in a badly tapered groove, tips from one side to other depending on forces (firing, compression, etc.) exerted upon it.

RING TRAVEL: The total distance a ring moves in cylinder from BDC to TDC. Ring travel and length of piston stroke are same.

RIVET: Metal pin used to hold two objects together. One end of the pin has head and other end must be set or peened over.

RIVET – COUNTERSUNK: A rivet, such as used on brake lining, in which head is sunk beneath lining surface to prevent rivet from striking drum, disc, etc.

RIVET – POP: A rivet useful for fastening two pieces together when rivet hole is accessible from one side only. Rivet is pushed through both pieces. When tool handles are compressed, a tapered pin is drawn back partly through rivet, thus expanding and tightening rivet in "blind" hole.

RMA: Rubber Manufacturer's Association.

ROAD CAMBER: Roads are not level. They are raised in center so that water will run off readily. This "crown" or angled surface is termed road camber.

ROAD CROWN: See Road Camber.

ROAD FEEL: Feeling imparted to steering wheel by wheels of car in motion. This feeling can be very important in sensing and predetermining vehicle steering response.

ROAD TEST: Process of driving vehicle upon road for purpose of diagnosing problems, checking efficiency of repairs, testing overall operation, etc.

ROCKER ARM: Arm used to direct upward motion of push rod into a downward or opening motion of valve stem. Used in overhead valve installations.

ROCKER ARM COVER: Stamped steel or plastic covering or shroud fastened to engine cylinder head so as to cover valve operating mechanisms.

ROCKER ARM SHAFT: Shaft upon which rocker arms are mounted.

ROCKER PANEL: Section of car body between front and rear fenders and beneath doors.

ROCKWELL HARDNESS: Measurement of the degree of hardness of given substance.

ROD: Refers to a car, driving a car hard, or to a connecting rod.

ROD CAP: Lower removable half of connecting rod big end.

RODDING THE RADIATOR: Top and sometimes the bottom tank of the radiator is removed. The core is then cleaned by passing a cleaning rod down through tubes. This is done when radiators are quite clogged with rust, scale, and various mineral deposits.

ROD HEATER: A device used to heat connecting rod small end to facilitate installation of piston pin.

ROLL BAR: Heavy steel bar that goes from one side of frame, up and around in back of the driver, and back down to the other side of frame. It is used to protect driver in the event that the car rolls over.

ROLL CABINET: A portable tool cabinet on small wheels or casters to facilitate moving about. Tool chest of drawers often is placed atop cabinet.

ROLLER BEARING: Bearing utilizing a series of straight, cupped, or tapered rollers engaging an inner and outer ring or race.

ROLLER CLUTCH: Clutch, utilizing series of rollers placed in ramps, that will provide drive power in one direction but will slip or freewheel in the other direction.

ROLLER LIFTER (Valve): A valve lifter incorporating a small roller on bottom end. Roller engages camshaft and allows lifter operation with a minimum of friction between lifter and cam lobe.

ROLLER TAPPETS or LIFTERS: Valve lifters that have roller placed on end contacting camshaft. This is done to reduce friction between lobe and lifter. They are generally used when special camshafts and high tension valve springs have been installed.

ROLLER-VANE PUMP: A vane pump, such as some fuel injection pumps, utilizing round rollers as operating vanes.

ROLLING CONTACT: Contact between moving parts, such as a roller against bearing race, where one part, instead of sliding, is rolling against other.

ROLLING FRICTION: Resistance to movement (friction) created by two moving objects in contact with each other – when one of the units is rolling across other. Will be less than sliding friction.

ROLLING RADIUS: Distance from road surface to center of wheel with vehicle moving under normal load. Rolling radius is dependent on tire size.

ROLLOVER VALVE: Valve in fuel delivery line to prevent escape of raw fuel during an accident in which car is upside down.

ROOM TEMPERATURE: An enclosed space air temperature of around 68-72°F (20.1-22.2°C).

ROOM TEMPERATURE VULCANIZING (RTV) SILICONE: A silicone sealing compound used as a gasket. Will set up or harden (vulcanize) at normal room temperature.

ROSIN CORE (Soldering): A wire solder with a hollow center filled with rosin flux. Used for soldering electrical connections.

ROTARY ENGINE: Piston engine in which the crankshaft is fixed (stationary) and in which cylinders rotate around crankshaft.

ROTARY ENGINE (Wankel): Internal combustion engine which is not of a reciprocating (piston) engine design. Central rotor turns in one direction only and yet effectively produces required intake, compression, firing, and exhaust strokes.

ROTARY FLOW (Torque converter): Movement of oil as it is carried around by pump and turbine. Rotary motion is not caused by oil passing through pump, to turbine, to stator, etc., as is case with vortex flow. Rotary flow is at right angles to centerline of converter whereas vortex flow is parallel (more or less depending on ratio between speeds of pump and turbine).

ROTARY INJECTION PUMP (Distributor type): A diesel injection pump one type of which uses a single pumping unit (two radial opposed pistons) to generate pressure for fuel distribution to all injectors. Fuel from pump passes through a distributor unit for proper injector delivery.

ROTARY MOTION: Continual motion in circular direction such as performed by crankshaft.

ROTARY VALVE (Steering): A power steering gear valve, that instead of moving back and forth, is rotated by steering gear shaft to open appropriate ports for hydraulic assist control.

ROTOR (DISC) LATERAL RUNOUT (Brakes): The amount of wobble or side to side (lateral) movement present when brake disc (rotor) is turned through one full revolution.

ROTOR (DISC) PARALLELISM (Brakes): Relates to how well one side of brake disc or rotor aligns (parallel) with other. Perfect parallelism is present when rotor thickness is constant at all points around rotor.

ROTOR (Distributor): Cap-like unit placed on end of distributor shaft. It is in constant contact with distributor cap central terminal and as it turns, it will conduct secondary voltage to one of the other terminals.

ROTOR PUMP: A pump, fuel, oil, etc., employing a multiple lobe roller operating inside of a rotating ring with corresponding rotor recesses. Liquid is trapped, carried around and squeezed out by enlargement and then reduction of spaces between inner and outer rotor.

ROUGHING STONE (Hone): Coarse stone used for quick removal of material during honing.

RPM: Revolutions per minute.

RUBBING BLOCK (Distributor): Insulated block attached to movable distributor point arm. Arm rubs against distributor cam and opens and closes points.

RUN-DOWN TORQUE: That torque required to turn fastener BEFORE it exerts closing pressure to parts. Caused by friction between fastener threads (dirt, battered threads, etc.).

RUNNING-FIT: Fit in which sufficient clearance has been provided to enable parts to turn freely and to receive lubrication.

RUNNING ON: See Dieseling.

RUNOUT: Rotating object, surface of which is not revolving in a true circle or plane. Runout can be measured in a radial (at right angles to centerline of object) direction or in a lateral (lengthwise to centerline) direction.

S

SAE: Society of Automotive Engineers.

SAE or RATED HORSEPOWER: A simple formula of long standing is used to determine what is commonly referred to as the SAE or Rated Horsepower. The formula is:

$$\frac{\text{Bore Diameter}^2 \times \text{Number of Cylinders}}{2.5}$$

This formula is used primarily for licensing purposes and is not too accurate a means of determining actual brake horsepower.

SAFE EDGE (File): A file in which one or more surface areas are smooth (no cutting edges at all). This allows filing one particular surface without danger of accidentally cutting an adjacent area.

SAFETY FACTOR: Providing strength beyond that needed, as an extra margin of insurance against part failure.

SAFETY HUBS: Device installed on the rear axle to prevent wheels from leaving car in event of a broken axle.

SAFETY RIM: Rim having two safety ridges, one on each lip, to prevent tire beads from entering drop center area in event of a blowout. This feature keeps tire on rim.

SAFETY VALVE: Valve designed to open and relieve pressure within a container when container pressure exceeds predetermined level.

SAFETY WIRE: Soft wire used to secure fasteners to prevent unscrewing from vibration, temperature changes, etc.

SAL AMMONIAC: A mineral (ammonium chloride), often used in block form upon which to rub a soldering copper to assist in proper tinning (getting a covering of solder on copper tip).

SAND BLAST: Cleaning by the use of sand propelled at high speeds in an air blast.

SAYBOLT VISCOMETER: Instrument used to determine fluidity or viscosity (resistance to flow) of an oil.

SCALE (Cooling system): Accumulation of rust and minerals within cooling system.

SCAN TOOL: A diagnostic tool used to extract trouble codes from an automobile's computer.

SCATTER SHIELD: Steel or nylon guard placed around bell or clutch housing to protect driver and spectator from flying parts in event of part failure at high rpm. Such a shield is often placed around transmissions and differential units.

SCAVENGING: Referring to a cleaning or blowing out action in reference to the exhaust gas.

SCHRADER VALVE: Valve, similar to spring loaded valve used in tire stem, used in car air conditioning system service valves.

SCORE: Scratch or groove on finished surface.

SCORED PISTON: A piston with vertical grooves and deep scratches in piston to cylinder contact surface. Caused by lack of lubrication, abrasive material such as hard carbon, fractured ring particles, etc.

SCORING: Producing deep scratches and grooves in a piston, bearing, etc., contact surface. Caused by insufficient lubrication, abrasive particles, etc.

SCREW CLAMP (Hose): A hose clamp that is tightened by means of a threaded screw.

SCREWDRIVER – CLUTCH: A screwdriver with a tip shaped somewhat like an hourglass. Used for clutch head screws.

SCREWDRIVER – OFFSET: A screwdriver in which tip is bent at an angle (usually 90 degrees) so as to turn screws in which there is little room between screw head and some other surface.

SCREWDRIVER – PHILLIPS: A screwdriver with a tip shaped somewhat like a cross in which cross arms are same width for their full length.

SCREWDRIVER – REED & PRINCE: A screwdriver in which tip is shaped somewhat like a cross in which cross arms are wider at outer edge and taper almost to a point where they intersect at center.

SCREWDRIVER – STANDARD: A screwdriver with a blade tip in which blade edge is same width across diameter of screwdriver. Used in all screws with a single, straight slot.

SCREWDRIVER – STUBBY: A very short screwdriver for use in cramped or restricted areas.

SCREW EXTRACTOR: Device used to remove broken bolts, screws, etc., from holes.

SCREW PITCH GAUGE: See Thread Gauge.

SCS: Speed Control Switch. (Speed sensitive spark advance control.)

SCUFFING: Very similar to scoring in many respects. Caused by lack of lubrication, improper clearance, etc. Metal particles are torn from one contact surface such as piston, and deposited on other, such as cylinder. Contact surfaces often discolored by heat produced.

SEAL: Device which prevents oil leakage around moving part.

SEAL DRIVER: A tool used to install seals.

SEALED BEAM HEADLIGHT: Headlight lamp in which lens, reflector, and filament are fused together to form single unit.

SEALED BEARING: Bearing that has been lubricated at factory and then sealed. It cannot be lubricated during service.

SEA LEVEL: Elevation as measured at ocean surface level. To avoid change in height caused by rise and fall of tide, middle (mean) level between high and low levels is used.

SEAT: Surface upon which another part rests or seats. Example: Valve seat is matched surface upon which valve face rests.

SEAT (Rings): Minor wearing of piston ring surface during initial use. Rings then fit or seat properly against the cylinder wall.

SECONDARY CIRCUIT (Ignition system): High voltage part of ignition system.

SECONDARY PISTON (Master cylinder): In a brake system dual master cylinder, that piston actuated by pressure generated by primary piston. Primary is actuated by either brake pedal linkage or power booster rod.

SECONDARY, REVERSE, or TRAILING BRAKE SHOE: Brake shoe that is installed facing rear of car.

SECONDARY WIRES: High voltage wire from coil to distributor central tower and from outer towers to spark plugs.

SECOND CUT FILE: A file with medium size (roughness) cutting edges.

SECTION HEIGHT (Tire): Distance, at right angles, from center of inside surface of tread area to a line intersecting (crossing through) two bead bottom edges. Calculated with tire mounted and at normal pressure.

SECTION MODULUS: Relative structural strength measurement of member (such as frame rail) that is determined by cross-sectional area and member shape.

SECTION WIDTH (Tire): Measurement of a tires' inside width at widest point between two sidewalls, when mounted and at normal pressure.

SECTOR GEAR: A partial gear, such as used on a steering gear pitman shaft, that is actually only a portion (pie shaped slice) of normal 360 degree gear. Gear can only be operated through a limited arc.

SECTOR SHAFT (Steering gear): Another term for pitman shaft. Has a sector gear (partial gear) on one end and pitman arm attached to other.

SEDIMENT: Accumulation of matter which settles to bottom of a liquid.

SEIZE: See Freezing.

SEIZED: A term describing condition of a bearing, shaft, pin, etc., that due to insufficient clearance, lack of lubrication, etc., has overheated. Through scuffing and galling, it is stuck fast and is thus unable to turn or slide.

SELF-ADJUSTING: A mechanism, linkage, series of related parts, etc., in which a required clearance is automatically maintained without need for periodic manual adjustment.

SELF-ALIGNING BEARING: A bearing that is secured in such a manner that it is free to pivot or swivel, thus permitting a certain amount of shaft lateral movement without binding bearing.

SELF-CENTERING BRAKES: Wheel brake design in which both brake shoe assemblies "float" and are free to move about so that when applied, center themselves in relation to brake drum.

SELF-DIAGNOSTICS: The ability of a computer to continuously monitor the operation of a specific system and send warning signals when an abnormal condition is detected.

SELF-ENERGIZING: Brake shoe (sometimes both shoes) that when applied develops wedging action that actually assists or boost braking force applied by wheel cylinder.

SELF-INDUCTION (Electromagnetic): Creation of voltage in a circuit by varying current in circuit.

SELF-LOCKING: A fastener utilizing built-in thread friction produced by tight threads, plastic plugs, neoprene rings, etc., so that when tightened it will not loosen under normal use.

SELF-STARTING ROD (Arc welding): An electric arc welding rod that utilizes a special flux coating that makes it very easy to get arc started and tends to automatically maintain proper rod to work distance as rod is consumed.

SELF-TAPPING: Fastener designed to cut its own thread as it is turned into hole.

SEMA: Specialty Equipment Manufacturer's Association.

SEMI-ELLIPTICAL SPRING: Spring, such as commonly used on truck rear axles, consisting of one main leaf and number of progressively shorter leaf springs.

SEMIFINISHED INSERT (Bearing): An insert bearing that following installation, must be machined to proper size by removing a certain amount of bearing material.

SEMIFLOATING (Drive axle): A drive axle in which drive shaft secures, aligns, and drives wheel. Supports weight of vehicle.

SENSOR: A device used to detect a change in heat, pressure, exhaust emissions, speed, etc., and to emit a suitable signal to a control unit.

SEPARABLE BEARING: A bearing capable of being disassembled.

SEPARATORS (Battery): Wood, rubber, or plastic sheets inserted between positive and negative plates to prevent contact.

SEQUENCE OF ASSEMBLY: Recommended order of operations involved in assembly of a transmission, starter, etc.

SERIES CIRCUIT: Circuit with two or more resistance units so wired that current must pass through one unit before reaching other.

SERIES-PARALLEL CIRCUIT: Circuit of three or more resistance units in which a series and a parallel circuit are combined.

SERVICEABLE: A part or unit whose design and construction permit disassembly for purposes of rebuilding. Can also be used to indicate a part or unit whose condition is such that it can still be used.

SERVICE CLASSIFICATION (Oil): A listing indicating ability of a specific oil to provide proper lubrication under specific engine operating conditions.

SERVICE MANAGER: Person in shop who greets customers, determines their needs, and assigns mechanics as required. Prepares cost estimates, handles service complaints, and in general, coordinates shop activity.

SERVICE VALVE (Air conditioning): A valve (hand or Schrader type) used to open sealed air conditioning system to perform discharge, charge, etc., operations.

SERVICE WRITER: Person who greets customer, determines their needs, and writes up necessary information (custom name, address, description of apparent trouble, etc.). As opposed to a service manager, service writer is primarily concerned with paperwork involved. Beyond this point, other persons take over.

SERVO (Transmission): Oil operated device used to push or pull another part—such as tightening the transmission brake bands.

SERVO ACTION: Brakes so constructed as to have one end of primary shoe bearing against end of secondary shoe. When brakes are applied, primary shoe attempts to move in the direction of the rotating drum and in so doing applies force to the secondary shoe. This action, called servo action, makes less brake pedal pressure necessary and is widely used in brake construction.

SETSCREW: A screw threaded through one part until it jams solidly against another, thus locking them together—such as a pulley to a shaft.

SHACKLE: Device used to attach ends of a leaf spring to frame.

SHAFT DRIVE ANGLE (Propeller shaft): Angle formed between center lines of propeller shaft and differential pinion shaft.

SHAFT RUNOUT: Amount of radial (up and down) movement that takes place during one complete revolution of shaft.

SHAVE: Removal of some chrome or decorative part.

SHAVE (Engine): Removal of metal from contact surface of cylinder head or block.

SHIFT FORKS: Devices that straddle slots cut in sliding gears. Fork is used to move gear back and forth on shaft.

SHIFT MECHANISM: Device for changing transmission gear range.

SHIFT POINT: Point, either in engine rpm or road speed, at which transmission should be shifted to next gear.

SHIFT RAILS: Sliding rods upon which shift forks are attached. Used for shifting the transmission (manual).

SHIFT RANGE (4-wheel drive): Used to refer to two speed transfer case gear position. Case can be shifted into HIGH RANGE (no gear reduction) or LOW RANGE (around two to one reduction).

SHIM: A thin piece of brass, steel, etc., inserted between two parts so as to adjust distance between them. Sometimes used to adjust bearing clearance.

SHIMMY: Front wheels shaking from side to side.

SHIM PACK: A bearing shim made up of numerous thin (.001 – .002 in.) laminations (layers). Bearing can be adjusted by removing a layer at a time until specified clearance is obtained.

SHOCK ABSORBER: Oil filled device used to control spring oscillation in suspension system.

SHOP SUPERVISOR: Person responsible for overall shop operation. Checks progress and quality of work, observance of safety rules, utilization and condition of shop, coordination between various departments, customer relations, etc.

SHORT or SHORT CIRCUIT: Refers to some "hot" portion of the electrical system that has become grounded. (Wire touching a ground and providing a completed circuit to the battery.)

SHORT BLOCK: Engine block complete with crankshaft and piston assemblies.

SHORTING HARNESS: An arrangement of wires that are used to short out (ground) spark plugs so as to perform engine cylinder balance test.

SHOT PEENING: A process utilizing a blast of small metal or plastic shot that is directed against surface of some part. Can be used for cleaning, piston expansion, relieving part surface tension, etc.

SHRINK-FIT: Fit between two parts which is so tight, outer or encircling piece must be expanded by heating so it will fit over inner piece. In cooling, outer part shrinks and grasps inner part securely.

SHROUD: Metal enclosure around fan, engine, etc., to guide and facilitate airflow.

SHUNT: An alternate or by-pass portion of an electrical circuit.

SHUNT LUBRICATION SYSTEM: An engine lubrication system that passes oil from pump through both filter and shunt (bypass) at all times. Oil from both then merges and passes to bearings.

SHUNT WINDING: Wire coil forming an alternate or by-pass circuit through which current may flow.

SIDE-DRAFT CARBURETOR: Carburetor in which air passes though carburetor into intake manifold in a horizontal plane.

SIDEWALL: Part of tire between tread and bead, has size and rating information.

SIGHT GLASS: Clear glass window in air conditioning line which lets mechanic check refrigerant for air bubbles (low refrigerant) and moisture (pink color).

SILENCER: Muffler.

SILVER SOLDER: Similar to brazing except that special silver solder metal is used.

SINGLE-BARREL, DOUBLE-BARREL, and FOUR-BARREL CARBURETORS: Number of throttle openings or barrels from the carburetor to the intake manifold.

SINGLE CUT FILE: A file utilizing a single row of angled cuts that are all parallel.

SINGLE LAP FLARE: A tubing flare in which a single layer of tubing is secured between fitting body and nut seal angles.

SINGLE PLATE CLUTCH: A clutch utilizing a single clutch disc secured between flywheel and pressure plate.

SINGLE POST FRAME LIFT: A vehicle lift utilizing one centrally located ram.

SINTERED BRONZE: Tiny particles of bronze pressed tightly together so that they form a solid piece. The piece is highly porous and is often used for filtering purposes.

SINTERING: Process involved in forming a part, such as a bushing, by heating (no melting involved) a compressed mass of copper, bronze, iron, etc., powder.

SIPE: Small slits in tire tread designed to increase traction. Also called kerfs.

SIPHON: Process of removing liquid from container by use of atmospheric pressure and gravity acting on a column of liquid in a hose, pipe, etc. One end of hose, pipe, etc., is submerged in liquid and other (discharge end) is held at a point below level of liquid in container.

SKID PLATE: Stout metal plate or plates attached to underside of vehicle to protect oil pan, transmission, fuel tank, etc., from damage caused by "grounding out" on rocks, curbs, and road surface.

SKIRT COLLAPSE (Piston): Condition in which diameter across piston skirt area has been reduced through action of heat and shock.

SKIRT THRUST SURFACE (Piston): That portion of piston skirt at right angles to piston pin when viewing piston from top.

SKIVING: Cutting away a portion of tire tread to correct out-of-round problem.

SKIVING HOSE: Removing one or more outer layers of hose rubber so that skived section can be pushed into a hose fitting. Usually involves removal of rubber down to first fabric layer.

SKIVING KNIFE: A special knife used to skive hose prior to insertion in fitting.

SLAG (Welding): Accumulation of hardened and burned flux left on weld area following brazing or arc welding in which flux was used.

SLAG INCLUSIONS (Welding): A weld in which weld metal contains particles of slag.

SLANT ENGINE: In-line engine with cylinder block tilted from vertical plane.

SLAVE CYLINDER (Hydraulic): In a hydraulic system, a cylinder containing a piston (such as a brake wheel cylinder) that is forced to move by pressure generated in another (connected) cylinder (such as brake master cylinder).

SLEEVE (Cylinder): See Cylinder Sleeve.

SLEEVE PULLER: Tool used to withdraw and install engine cylinder sleeves.

SLIDE HAMMER: A pulling device that utilizes a sliding weight that can be hammered against a portion of handle to generate pulling force.

SLIDING FIT: See Running-Fit.

SLIDING FRICTION: Friction (resistance to movement) between two parts in which surface of one is sliding over surface of other.

SLIDING GEAR: Transmission gear splined to the shaft. It may be moved back and forth for shifting purposes.

SLIP ANGLE: Difference in actual path taken by a car making a turn and path it would have taken if it had followed exactly as wheels were pointed.

SLIP JOINT: Joint that will transfer driving torque from one shaft to another while allowing longitudinal movement between two shafts.

SLIPPER PUMP: A pump using spring-loaded, slipper-like vanes riding in grooves in a rotor. Rotor operates inside a cam shaped ring.

SLINGSHOT: Form of dragster using rather long thin frame with a very light front axle and wheel assembly.

SLITTING FILE: A four surfaced file with a parallelogram cross section.

SLOTTED ANCHOR: A wheel brake design in which brake shoe anchor is passed through a slotted opening in backing plate, thus allowing anchor to be moved for accurate shoe-to-drum centering.

SLOW CHARGING (Battery): Recharging a battery by passing a low current (5 to 7 amps) through it for a relatively long period (14 to 24 hours).

SLOW IDLE: Normal hot engine idle speed.

SLUDGE: Black, mushy deposits throughout interior of the engine. Caused from mixture of dust, oil, and water being whipped together by moving parts.

SMALL HOLE GAUGE: A device used to measure inside diameter of small holes. Gauge is adjusted to hole and gauge is then measured with an outside micrometer.

SMOG: Fog made darker and heavier by chemical fumes and smoke.

SNAP RING: Split ring snapped into a groove in a shaft or in a groove in a hole. It is used to hold bearings, thrust washers, gears, etc., in place.

SNUBBER: Device used to limit travel of some part.

SOAKING TANK: A cleaning tank in which parts are submerged for a recommended period in some type of cleaner.

SOCKET ADAPTER: A device used to allow a socket with one particular drive size to be used with another different drive size (1/4 in., 3/8 in., etc.) handle ratchet, etc.

SOCKET – SIX-POINT (Wrench): A socket with a hexagonal (six sided) shaped hole. Grips fastener flats across entire surface. Has six inside corners.

SOCKET – TWELVE-POINT (Wrench): Socket with twelve inside corners that produce twelve short gripping areas. Engages only a portion of each fastener flat.

SOCKET – SWIVEL (Wrench): A socket with an integral swivel drive unit.

SOCKET – UNIVERSAL JOINT: A swivel type device that allows socket to be operated at various angles.

SODIUM VALVE: Valve in which stem has been partially filled with metallic sodium to speed up transfer of heat from valve head, to stem and then to guide and block.

"SOFT" WATER: Water containing a minimum amount of minerals such as calcium, magnesium, etc.

SOHC: Engine with single overhead camshaft.

SOLDERED ON (Terminal): A wire terminal that is attached to wire by soldering.

SOLDERING: Joining two pieces of metal together with lead-tin mixture. Both pieces of metal must be heated to insure proper adhesion of melted solder.

SOLDERING FLUX: A cleaning agent (rosin or acid type) that is placed on parts to be soldered. Prevents oxidization of surface and greatly assists in solder flow and adhesion.

SOLDERING GUN: Electrically heated soldering iron shaped somewhat like a pistol. Trigger switch sends current through copper tip, raising it to soldering heat. Usually used for light soldering such as done on wiring.

SOLENOID: Electrically operated magnetic device used to operate some unit. Movable iron core is placed inside of coil. When current flows through coil, core will attempt to center itself in coil. In so doing, core will exert considerable force on anything it is connected to.

SOLID AXLE: Single beam runs between both wheels. May be used on either front or rear of car.

SOLID STATE: An electrical device, such as a regulator, that has no moving parts. Such units use transistors, diodes, resistors, etc., to perform all electrical functions.

SOLVENT: Liquid used to dissolve or thin other material. Examples: Alcohol thins shellac; gasoline dissolves grease.

SPADE TERMINAL: A male electrical connector with a single, slotted, flat blade.

SPALLING (Bearing): A condition in which tiny areas of bearing surface have flaked off. As flaking accelerates, large craters can be formed.

SPARK: Bridging or jumping of a gap between two electrodes by current of electricity.

SPARK ADVANCE: Causing spark plug to fire earlier.

SPARK ARRESTOR: Device used to prevent sparks (burning particles of carbon) from being discharged from exhaust pipe. Usually used on off-road equipment to prevent forest fires.

SPARK GAP: Space between center and side electrode tips on a spark plug.

SPARK KNOCK: See Preignition.

SPARK LIGHTER (Welding): A flint and steel device used to produce sparks with which to light an oxyacetylene torch.

SPARK PLUG: Device containing two electrodes across which electricity jumps to produce a spark to fire fuel charge.

SPARK PLUG HEAT RANGE: An indication of how fast plug transfers heat from insulator tip, through insulator to shell and into head and atmosphere. Longer or narrower insulator, produces hotter plug.

SPARK PLUG OIL FOULING: Buildup of oil deposit caused by worn valve guides, leaking rings, etc., allowing an excessive amount of oil to enter combustion chamber.

SPARK PLUG REACH: Distance from plug-to-head contact surface (gasket or taper) to end of threaded nose section.

SPARK PLUG SIZE: Relates to outside diameter (major thread diameter) of threaded nose section.

SPARK PLUG TYPE: Refers to plug construction, such as resistor, nonresistor, single electrode, etc.

SPECIALIZATION: Mechanic concentrated in one particular area of auto repair—brakes, tune-up, transmission, engines.

SPECIFIC GRAVITY: Relative weight of a given volume of specific material as compared to weight of an equal volume of water.

SPEED: Time rate of motion without regard to direction. Forward speed (mph or km/h) of a vehicle, rotational speed (rpm) of an engine, etc.

SPEED HANDLE: A socket hand tool with an offset (crank) area that permits rapid and full rotation of socket.

SPEEDOMETER: Instrument used to determine forward speed of an auto in miles per hour or kilometres per hour.

SPHERICAL ROLLER (Bearing): A bearing roller in which center outside diameter exceeds that of either end giving roller a convex (barrel shape).

SPIDER GEARS: Small gears mounted on shaft pinned to differential case. They mesh with, and drive, the axle end gears.

SPINDLE (Wheel): Machined shaft upon which inside races of front wheel bearings rest. Spindle is an integral part of steering knuckle.

SPIN-ON FILTER: An engine oil filter that is a complete unit (case and filter) in itself. It is attached by merely threading it onto a short section of pipe. Cannot be disassembled for cleaning.

SPIRAL BEVEL GEAR: Ring and pinion setup widely used in automobile differentials. Teeth of both ring and pinion are tapered and are cut on a spiral so that they are at an angle to centerline of pinion shaft.

SPIRIT LEVEL: A leveling device using a floating "bubble" visible inside a glass tube.

SPLINE: Metal (land) remaining between two grooves. Used to connect parts.

SPLINED JOINT: Joint between two parts in which each part has splines cut along contact area. Splines on each part slide into grooves between splines on other part.

SPLIT KEEPERS (Valve): Valve spring retainer lock made up of a two piece tapered cone that wedges between retainer and valve stem grooves.

SPLIT MANIFOLD: Exhaust manifold that has a baffle placed near its center. An exhaust pipe leads out of each half.

SPONGY PEDAL: When there is air in brake lines, or shoes that are not properly centered in drums, brake pedal will have a springy or spongy feeling when brakes are applied. Pedal normally will feel hard when applied.

SPOOL BALANCE VALVE (Automatic Transmission): Hydraulic valve that balances incoming oil pressure against spring control pressure to produce a steady pressure to some control unit.

SPOOL VALVE: Hydraulic control valve shaped somewhat like spool upon which thread is wound.

SPORTS CAR: Term commonly used to describe a relatively small, low slung, car with a high performance engine.

SPOT WELD: Fastening parts together by fusing, at various spots. Heavy surge of electricity is passed through the parts held in firm contact by electrodes.

SPRAG CLUTCH: Clutch that will allow rotation in one direction but that will lock up and prevent any movement in the other direction.

SPRING (Main leaf): Long leaf on which ends are turned to form an "eye" to receive shackle.

SPRING BOOSTER: Device used to "beef" up sagged springs or to increase the load capacity of standard springs.

SPRING CAPACITY AT GROUND: Total vehicle weight (sprung and unsprung) that will be carried by spring bent or deflected to its maximum normal loaded position.

SPRING CAPACITY AT PAD: Total vehicle sprung weight that will be carried by spring bent or deflected to its normal fully loaded position.

SPRING FREE LENGTH (Valve): Overall length of a coil spring when all compression forces are removed.

SPRING LOADED: Device held in place, or under pressure from a spring or springs.

SPRING OSCILLATION: Rapid compression and rebound movement that exists in a coil spring following a sudden change in loading pressure.

SPRING REBOUND: Reverse direction spring movement following sudden compression (loading). Spring attempts to return to its original position.

SPRING SCALE: A weighing device using a

coil spring that is stretched as pressure is applied. Stretching is indicated by a needle moving along a scale.

SPRING SKIRT EXPANDER (Piston): A spring steel device inserted inside a piston to apply outward (expansion) pressure to skirt thrust surfaces.

SPRING SQUARENESS (Valve spring): Refers to angle of spring ends as related to spring centerline. Should be perfectly square (90 degrees).

SPRING STEEL: Heat treated steel having the ability to stand a great amount of deflection and yet return to its original shape or position.

SPRING WINDUP: Curved shape assumed by rear leaf springs during acceleration or braking.

SPROCKET: Toothed wheel used to drive chain or cogged belt.

SPRUNG WEIGHT: Weight of all parts of car that are supported by suspension system.

SPUR GEAR: Gear on which teeth are cut parallel to shaft.

SPURT or SQUIRT HOLE: Small hole in connecting rod big end that indexes (aligns) with oil hole in crank journal. When holes index, oil spurts out.

SQUARE ENGINE: Engine in which bore diameter and stroke are of equal dimensions.

SQ. FT.: Square Foot.

SQ. IN.: Square Inch.

STABILIZER BAR: Transverse mounted spring steel bar that controls and minimizes body lean or tipping on corners.

STAKED INSERT (Valve): A valve seat insert that is held in recess by extruding some of head metal over seat edge by hammering metal with a special punch.

STAKED NUT: Nut held in position by staking (forcing a part of nut into a groove, hole, etc., in other part).

STAKING: Holding a nut, pin, etc., into place by hammering a portion of part into a groove, cutout, etc., in mating part. This prevents turning, sliding, etc., movement. A staking punch, with an appropriate nose, is needed.

STALL: To stop rotation or operation.

STALL TEST (Automatic transmission): Testing torque converter-transmission action by applying full engine load (wide open throttle) with transmission in gear and brakes FIRMLY applied. Must be very brief test (5 seconds). Engine rpm is noted at full stall.

STALL TORQUE (Starter): Full torque developed by starter motor when pinion is prevented from turning.

STAMPING: Sheet metal part formed by pressing between metal dies.

STARTER (Engine): Electric motor which uses a geardrive to crank (spin) engine for starting.

STARTER PINION GEAR: Small gear on end of starter shaft that engages and turns large flywheel ring gear.

STARTER SOLENOID: Large electric relay that makes and breaks the electrical connection between the battery and starting motor.

STARTING PUNCH: A punch, with a tapered nose, used to start pins out of their holes.

STARTING SYSTEM: Parts (starter motor, gear drive, switch, solenoid, wires, battery, etc.) used to crank car for starting.

STAR WHEEL (Brakes): A small brake shoe adjusting wheel with a series of radial prongs that can be engaged by tip of a screwdriver so as to turn wheel.

STATE OF CHARGE (Battery): Refers to amount of potential electrical energy present in battery at time of testing. Indicated by specific gravity of electrolyte.

STATIC BALANCE: When a tire, flywheel, crankshaft, etc., has an absolutely even distribution of weight mass around axis of rotation, it will be in static balance. For example, if front wheel is jacked up and tire, regardless of where it is placed, always slowly turns and stops with the same spot down, it would not be in static balance. If, however, wheel remains in any position in which it is placed, it would be in static balance. (Bearings must be free, no brake drag, etc.)

STATIC ELECTRICITY: Electricity generated by friction between two objects. It will remain in one object until discharged.

STATIC PRESSURE (Brakes): Pressure that always exists in brake lines—even with brake pedal released. Static pressure is maintained by a check valve.

STATIC RADIUS: Distance from road surface to center of wheel with vehicle normally loaded, at rest.

STATIC SUPPRESSION: Removal or minimizing of unwanted electromagnetic waves that cause radio static interference (hissing, crackling, etc.).

STATOR: Small hub, upon which series of vanes are affixed in radial position, that is so placed that oil leaving torque converter turbine strikes stator vanes and is redirected into pump at an angle conducive to high efficiency. Stator makes torque multiplication possible. Torque multiplication is highest at stall when the engine speed is at its highest and the turbine is standing still.

STEAM CLEANING: Cleaning by using a jet of steam directed against surface to be cleaned.

STEEL DRIFT: A steel bar, heavy punch, etc., that is placed against an object so that it can be moved by hammering against drift.

STEEL PACK MUFFLER: Straight-through (no baffles) muffler utilizing metal shavings surrounding a perforated pipe. Quiets exhaust sound.

STEERING ARMS: Arms, either bolted to, or forged as an integral part of steering knuckles. They transmit steering force from tie rods to knuckles, thus causing wheels to pivot.

STEERING AXIS INCLINATION: See Kingpin Inclination.

STEERING GEAR: Gears, mounted on lower end of steering column, used to multiply driver turning force.

STEERING GEOMETRY: Term sometimes used to describe various angles assumed by components making up front wheel turning arrangement, camber, caster, toe-in, etc.

Also used to describe related angles assumed by front wheels when car is negotiating a curve.

STEERING KNUCKLE: Inner portion of spindle affixed to and pivoting on either a kingpin or on upper and lower ball joints.

STEERING KNUCKLE ANGLE: Angle formed between steering axis and centerline of spindle. This angle is sometimes referred to as Included Angle.

STEERING LINKAGE: Various arms, rods, etc., connecting steering gear to front wheels.

STEERING SYSTEM: All parts (steering wheel, shaft, gears, linkage, etc.) used in transferring motion of steering wheel to front wheels.

STELLITE: Extremely hard metal (mix of chromium, tungsten, cobalt, etc.) often used for exhaust valve seats, valve face, etc., on heavy duty engines.

STETHOSCOPE: Device (as used by doctors) to detect and locate abnormal engine noises. Handy tool for troubleshooter.

STICK SHIFT: Transmission that is shifted manually through use of various forms of linkage. Often refers to upright gearshift stick that protrudes through floor.

Either floor or steering column mounted manual shift device for transmission.

STOCK CAR: Car as built by factory.

STOICHIOMETRIC FUEL MIXTURE: A fuel mixture in which proportions of air and fuel are such as to permit complete burning. The ideal mixture for any given engine and set of conditions.

STONE DRESSER: A device used to cut a new surface on a grinding wheel or stone. May be diamond tipped or mechanical star wheel type.

STONE SLEEVE (Valve): Cylindrical unit upon which engine valve seat grinding stone is attached. Sleeve slips over and is guided by pilot. Also termed "mandrel."

STONE SLEEVE PILOT (Valve): Rigid metal rod that is twisted into valve guide with upper protruding portion acting as a guide or pilot for grinding stone sleeve.

STONE TRUING (Valve): Cutting a fresh, correct surface on a grinding stone by passing a diamond tipped dresser across stone at correct angle.

STOPLIGHT: Warning lights, red in color, attached to rear of vehicle. Stoplights come on whenever brake pedal is depressed.

STORAGE BATTERY: Another term for car battery. See Battery.

STOVEBOLT: Generally refers to Chevrolet (GMC) 6-cylinder, in-line, valve-in-head (push rod operated) engine.

STRAIGHTEDGE (Steel): Long, flat, relatively thin, steel strip with perfectly straight edges. Used for drawing straight lines, checking surfaces for warpage, etc.

STRAIGHT POLARITY (Welding): In DC arc welding, having current flow from machine negative terminal (rod holder cable attached to NEG. terminal) through electrode to work and then on through ground cable to machine positive terminal.

STRAIGHT ROLLER (Bearing): A bearing roller in which roller outside diameter is constant from one end to other.

STRANDING (Wire): Center current carrying portion of an insulated wire. Can be of copper, aluminum, etc., and can be of one piece or multi-wire construction. Automotive wire is of multi-strand construction for great flexibility without breakage.

STREET ROD: Slightly modified rod that will give good day-to-day performance on the streets.

STRESS: To apply force to an object. Force or pressure an object is subjected to.

STRIKING AN ARC (Welding): Scratching arc welding electrode along workpiece to establish an arc producing current flow.

STRIPING TOOL: Tool used to apply paint in long narrow lines.

STROBOSCOPE: See Timing Light.

STROKE: Distance piston moves when traveling from TDC to BDC.

STROKED CRANKSHAFT: Crankshaft, either special new one or stock crank reworked, that has connecting rod throws offset so that length of stroke is increased.

STROKER: Engine using crankshaft that has been stroked.

STUD: Metal rod with threads on both ends.

STUD PULLER: Tool used to install or remove studs.

SUB-SPECIALIST: A person specializing within a speciality—such as a person handling fuel injection pumps exclusively, even though fuel injection pumps would be under general area of a fuel system specialist.

SUCTION: See Vacuum.

SUCTION LINE: See Low Pressure Line.

SUCTION THROTTLING VALVE: Valve placed between air conditioning evaporator and compressor which controls evaporator pressure to provide maximum cooling without icing evaporator core.

SULFATION: Formation of lead sulphate on battery plates.

SULPHURIC ACID (Battery): Acid (36%) that is mixed with water (64%) to form battery electrolyte. DANGER—a powerful acid, wear goggles and rubber gloves. Add acid to water—NEVER ADD WATER TO ACID!

SUMP: Part of oil pan that contains oil.

SUN GEAR: Center gear around which planet gears revolve.

SUPER CAR: Car with high horsepower engine that will provide fast acceleration and high speed.

SUPERCHARGER: Unit designed to force air, under pressure, into cylinders. Can be mounted between carburetor and cylinders or between carburetor and atmosphere.

SUPERHEAT SWITCH: See Compressor Protection Switch.

SURE-GRIP DIFFERENTIAL: High traction differential which causes both axles to rotate under power.

SURFACE TYPE FILTER: A filter in which filtering medium traps dirt, abrasives, etc., on surface. A paper filter (without additional depth filtering material) would be a surface type filter.

SURGE BLEEDING (Brakes): Rapid stroke of brake pedal (with pressure bleeder attached to master cylinder reservoir and wheel bleed screw open) to cause a violent surge of fluid into wheel cylinder in order to remove trapped air.

SUSPENSION HEIGHT: A specified distance from one or more suspension components (such as suspension lower arm) to either floor or to some spot on body. This will establish correct suspension arm, spring, etc., heights and/or angles in relation to vehicle frame or body.

SUSPENSION LIFT: A lift that raises vehicle by engaging only front and rear suspension systems (such as front, lower suspension arms and rear axle housing).

SWAGED INSERT (Valve): An engine valve seat insert that is held in its recess by swaging (rolling pressure that forces metal to flow or extrude), thus locking seat by forcing head metal over a chamfer cut on seat outside diameter.

SWAY BAR: See Stabilizer Bar.

SWEATING: Joining two pieces of metal together by placing solder between them and then clamping them tightly together while heat, sufficient to melt the solder, is applied.

SWING AXLE: Independent rear suspension system in which each driving wheel can move up or down independently of other. Differential unit is bolted to frame and various forms of linkage are used upon which to mount wheels. Drive axles, utilizing one or more universal joints, connect differential to drive wheels.

SWITCH: (Electric): A device to make (complete) or break (interrupt) flow of current through a circuit.

SYNCHROMESH TRANSMISSION: Transmission using device (synchromesh) that synchronizes speeds of gears that are being shifted together. This prevents "gear grinding." Some transmissions use synchromesh on all shifts, while others synchronize second and high gearshifts.

SYNCHRONIZE: To bring about a timing that will cause two or more events to occur simultaneously; plug firing when the piston is in correct position, speed of two shafts being the same, valve opening when piston is in correct position, etc.

SYNCHRONIZE (Transmission): A friction device to bring two transmission gears to same rotational speed before meshing. Avoids clashing gears.

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TACHOMETER: Device used to indicate speed of engine in rpm.

TAILLIGHT: Lights, usually red or amber, attached to rear of vehicle. Lights operate in conjunction with headlights.

TAIL PIPE: Exhaust piping running from muffler to rear of car.

TANK GAUGE UNIT: Variable resistor device in fuel tank. It operates fuel gauge in dashboard.

TAP: To cut threads in a hole, or can be used to indicate fluted tool used to cut threads.

TAP AND DIE SET: Set of taps and dies for internal and external threading—usually covers a range of the most popular sizes.

TAP – BOTTOMING: Internal thread cutting tool designed to cut full threads completely to bottom of a hole.

TAPERED END AXLE: Axle using a tapered end upon which wheel hub is secured by means of a key and attaching nut.

TAPERED ROLLER (Bearing): Cone shaped bearing roller.

TAPERED ROLLER BEARING (Antifriction): Bearing utilizing series of tapered, hardened steel rollers operating between an outer and inner hardened steel race.

TAPPET: Screw used to adjust clearance between valve stem and lifter or rocker arm.

TAPPET CLEARANCE: On non-hydraulic lifter setups, operating clearance that exists in valve train to prevent valve from being held open when parts heat up and elongate.

TAPPET NOISE: Noise caused by lash or clearance between valve stem and rocker arm or between valve stem and valve lifter.

TAP – PIPE: An internal thread cutting tool that cuts threads suitable for pipe fittings.

TAP – PLUG: An internal thread cutting tool with a slight nose taper—between a taper and bottoming tap.

TAP – TAPER: Internal thread cutting tool on which first few threads have been ground to form a tapered nose shape. This permits tap nose to enter partway into hole, making it easier to start cutting threads.

TAP WATER: Water as drawn from a typical household faucet. Depending upon source, can be either "hard" or "soft."

TCS: Transmission Controlled Spark.

TDC: Top Dead Center.

TEFLON: Plastic with excellent self-lubricating (slippery) bearing properties.

TELESCOPING GAUGE: Measuring tool consisting of a spring loaded collapsible rod affixed at right angles to a locking handle. Used to measure inside diameter of holes.

TEMPER: To effect a change in physical structure of piece of steel through use of heat and cold.

TEMPERATURE GAUGE: Dash mounted instrument to indicate temperature of engine coolant. May be operated electrically or by Bourdon tube.

TENSILE STRENGTH: An indication of how much stretching force a material can withstand before it breaks.

TENSION: Pulling or stretching stress applied to an object.

TENSION LOADING: Placing a load, in such a manner, as to apply a pulling or stretching force to an object. A torqued fastener is under tension loading.

TERMINAL: Connecting point in electric circuit. When referring to battery, it would indicate two battery posts.

TERMINAL BLOCK (Electrical): A central distribution block that receives current from one wire and through means of a bus bar, conducts it to a number of others.

TEST LAMP: A light bulb wired in series with a battery and two test wire leads. Used to check circuits, grounds, opens, etc.

T-FITTING: A T-shaped fitting that may be inserted into a line for purpose of attaching an additional line at same point.

T-HANDLE: Socket wrench extension with a round rod handle passed through it at right angles at one end. Other end has square socket drive connection tip.

T-HEAD ENGINE: Engine having intake valve on one side of cylinder and exhaust on other.

THERMAL BULB: A temperature sensitive device consisting of a hollow bulb filled with liquid, connected by means of a capillary tube to a control unit, dial, etc.

THERMAL EFFICIENCY: Percentage of heat developed in burning fuel charge that is actually used to develop power determines thermal efficiency. Efficiency will vary according to engine design, use, etc. If an engine utilizes great deal of heat to produce power, its thermal efficiency would be high.

THERMAL SENSOR: A temperature sensitive sensor.

THERMAL TIME SWITCH (Carburetion): A time controlled switch that is also temperature sensitive. Used with some fuel injection system cold start valves.

THERMISTOR: Resistor that changes its resistance in relation to temperature.

THERMOSTAT: Temperature sensitive device used in cooling system to control flow of coolant in relation to temperature.

THERMOSTATICALLY CONTROLLED AIR CLEANER (TAC): An emission control device used to control temperature of air entering air cleaner. Cleaner receives heated air during engine warmup.

THERMOSTATIC SPRING: A heat sensitive, bimetallic (two kinds of metal) spring that winds or unwinds as temperature changes take place.

THERMOSTATIC SWITCH: A switch that is actuated by temperature changes.

THIRD BRUSH (Generator): Generator in which a third, movable brush is used to control current output.

THREAD LENGTH: A measurement of length of threaded area on a bolt, capscrew, etc.

THREAD-PITCH GAUGE: A gauge used to determine number of threads per inch on a fastener. Consists of many leaves, each with a specific thread cut on one edge.

THREE-QUARTER FLOATING (Axle): A drive axle that secures, aligns, and drives wheel. Does not support vehicle weight.

THREE-QUARTER RACE CAMSHAFT: Description of custom camshaft indicating type of lobe grinding which, in turn, dictates type of use. Other grinds are one-quarter race, full-race, street-grind, etc.

THREE-WAY CATALYTIC CONVERTER: Converter, sometimes called dual converter, that combines both an oxidizing and reducing catalyst. Controls NOx, CO, and HC emissions.

THROTTLE RETURN DASHPOT: Carburetor device which slows throttle closing and prevents stalling.

THROTTLE VALVE: Valve in carburetor. It is used to control amount of fuel mixture that reaches cylinders.

THROTTLE VALVE SENSOR and THROTTLE POSITION SENSOR: Sensor which measures amount of throttle valve opening and provides information for fuel injection computer.

THROTTLE VALVE (Transmission): Valve in automatic transmission which controls oil flow to regulator plug.

THROW: Offset portion of crankshaft designed to accept connecting rod.

THROWING A ROD: When an engine has thrown a connecting rod from crankshaft, major damage is usually incurred.

"THROW OFF" OIL: Lubricating oil that is thrown outward from rotating parts.

THROW-OUT BEARING (Clutch): Bearing that is forced against clutch throw-out fingers to release clutch.

THROW-OUT LEVER (Clutch): Pivoted lever that actuates clutch throw-out bearing.

THROW-OUT SLEEVE (Clutch): Sliding sleeve upon which clutch throw-out bearing is mounted. Actuated by throw-out lever.

THRUST: A pushing or shoving force exerted against one body by another.

THRUST BEARING: Bearing designed so as to resist side pressure.

THRUST FLANGE: A shoulder on a shaft that rides against a thrust bearing to control end play and thrust forces.

THRUST LOADING: Load force applied parallel to crankshaft, camshaft, etc., centerline.

THRUST SURFACE: That portion (surface) of a part that either receives or transmits a force from or to another part.

THRUST WASHER: Bronze or hardened steel washer placed between two moving parts. The washer prevents longitudinal movement and provides a bearing surface for thrust surfaces of parts.

TIE ROD: Rod, or rods, connecting steering arms together. When tie rod is moved, wheels pivot.

TIG: Gas tungsten arc welding (Tungsten Inert Gas).

TIGHTENING SEQUENCE: Order in which fasteners should be tightened or torqued to prevent part distortion.

TIMED FUEL INJECTION: Fuel injection is timed to occur when intake valve opens.

TIMING: The act of coordinating two or more separate events or actions in relation to each other. Example: Timing the firing of plug to piston position on compression stroke.

TIMING BELT: A flexible, toothed belt used to rotate camshaft.

TIMING CHAIN: Drive chain that operates camshaft by engaging sprockets on camshaft and crankshaft.

TIMING COVER: Cover over front of engine. Houses timing chain or gear mechanism and front crankshaft oil seal.

TIMING GEARS: Both the gear attached to the camshaft and the gear on the crankshaft. They provide a means of driving the camshaft.

TIMING LIGHT: Stroboscopic unit that is connected to secondary circuit to produce flashes of light in unison with firing of specific spark plug. By directing these flashes of light on whirling timing marks, marks appear to stand still. By adjusting distributor, timing marks may be properly aligned, thus setting timing.

TIMING MARKS (Ignition): Marks, usually located on vibration damper, used to synchronize ignition system so plugs will fire at precise time.

TIMING MARKS (Valves): One tooth on either the camshaft or crankshaft gear will be marked with an indentation or some other mark. Another mark will be found on other gear between two of teeth. Two gears must be meshed so that marked tooth meshes with marked spot on other gear.

TIMING SPROCKETS: Chain or belt type sprockets on crankshaft and camshaft.

TINNING: Coating piece of metal with a very thin layer of solder.

TIN-PLATED: Covered with a very thin coating of tin.

TIR (Total Indicator Reading): Dial indicator needle reading amount from lowest to highest reading produced by a complete rotation of a gear, shaft, etc.

TIRE BALANCE: In that tires turn at relatively high speeds, they must be carefully balanced both for static balance and for dynamic balance.

TIRE BEAD: Portion of tire that bears against rim flange. Bead has a number of turns of steel wire in it to provide great strength.

TIRE CASING: Main body of tire exclusive of tread.

TIRE INFLATION PRESSURE: Recommended maximum tire air pressure as given on tire sidewall.

TIRE PLIES: Layers of nylon, rayon, etc., cloth used to form casing. Many car tires are two ply with a four ply rating. Two ply indicates two layers of cloth or plies.

TIRE ROTATION: Moving front tires to rear and rear to front to equalize any wear irregularities.

TIRE SIDEWALL: Portion of tire between tread and bead.

TIRE SIZE: Given on tire sidewall as coded letter-number designation of size, section height, and diameter across bead.

TIRE TREAD: Part of tire that contacts road.

TOE-IN: Having front of wheels closer together than back (front wheels). Difference in measurement across front of wheels and the back will give amount of toe-in.

TOE-OUT: Having front of wheels further apart than the back.

TOE-OUT ON TURNS: When car negotiates a curve, inner wheel turns more sharply and while wheels remain in this position, a condition of toe-out exists.

TOGGLE SWITCH: Switch actuated by flipping a small level either up and down or from side to side.

TOLERANCE: Amount of variation permitted from an exact size or measurement. Actual amount from smallest acceptable dimension to largest acceptable dimension.

TOOTH CONTACT PATTERN: Refers to shape, size, and location of actual contact area between two mating gear teeth.

TOOTH HEEL (Differential ring gear): Wider outside end of tooth.

TOOTH TOE (Differential ring gear): Narrower inside end of tooth.

TOP OFF: Fill a container to full capacity.

TORQUE: Turning or twisting force such as force imparted on drive line by engine.

TORQUE ARM: An arm or lever attached to some part to control amount and direction of movement caused by torque (twisting) forces.

TORQUE BAR or ROD: An articulated bar between frame and drive axle housing designed to relieve leaf springs of axle torque (twisting) strain. Prevents axle windup and/or hop during heavy acceleration or braking. Also called Traction Bar.

TORQUE CONVERTER: Unit, quite similar to fluid coupling, that transfers engine torque to transmission input shaft. Unlike fluid coupling, torque converter can multiply engine torque. This is done by installing one or more stators between torus members. Driving torus is referred to as "pump" and driven torus as "turbine."

TORQUE (Gross): Maximum engine torque developed by engine without fan, air cleaner, alternator, exhaust system, etc.

TORQUE (Net): Maximum torque developed by engine equipped with fan, air cleaner, exhaust system, and all other systems or units present when engine is installed in vehicle.

TORQUE MULTIPLICATION (Automatic transmission): Increasing engine torque through the use of a torque converter.

TORQUE TUBE DRIVE: Method of connecting transmission output shaft to differential pinion shaft by using an enclosed drive shaft. Drive shaft is enclosed in torque tube that is bolted to rear axle housing on one end and is pivoted through a ball joint to rear of transmission on other. Driving force of rear wheels is transferred to frame through torque tube.

TORQUE WRENCH: Wrench used to draw nuts, cap screws, etc., up to specified tension by measuring torque (turning force) being applied.

TORQUING SEQUENCE: See Tightening Sequence.

TORSIONAL VIBRATION: Twisting and untwisting action developed in shaft. It is caused either by intermittent applications of power or load.

TORSION BAR: Long spring steel rod attached in such a way that one end is anchored while other is free to twist. If an arm is attached at right angles to free end, any movement of arm will cause rod or bar to twist. Bar's resistance to twisting provides a spring action. Torsion bar replaces both coil and leaf springs in some suspension systems.

TORSION BAR SUSPENSION: Suspension system that makes use of torsion bars in place of leaf or coil spring.

TORUS: Fluid coupling rotating member. There are two—driving and driven torus.

TOTE BOARD: Portable board or rack containing a series of tools such as pullers and accessories.

TOTE TRAY: Portable tray for tools. May be hand carried to work area.

TOXIC: Poisonous.

TPC: Tire Performance Criteria.

TRACK: Distance between front wheels or distance between rear wheels. They are not always the same.

TRACTION BAR: Articulated bar or link attached to frame and rear axle housing to prevent spring windup during heavy acceleration or braking.

TRACTION CONTROL: Computerized system that governs engine throttle and brake system operation to increase vehicle stability on low-friction surfaces.

TRACTION DIFFERENTIAL: See Limited-Slip Differential.

TRACTION (Tire): Frictional force generated between tire and road. Necessary for braking, steering, and driving.

TRAMMEL: Steel bar or rod with adjustable, sliding indicator arms. Used to check measurements between parts. Often used for checking wheel and tire toe-in.

TRAMP: Hopping motion of front wheels.

TRANSAXLE: Drive setup in which transmission and differential are combined into a single unit.

TRANSDUCER: Vacuum regulator actuated or controlled electrically. A device that converts an input signal (electrical) into an output signal (diaphragm movement) of a different form.

TRANSFER CASE: Gearbox, driven by transmission, that will provide driving force to both front and rear propeller shafts on four-wheel drive vehicle.

TRANSFORMER: Electrical device used to increase or decrease voltage. Car ignition coil transforms voltage from 12 volts to upward of 30,000 volts.

TRANSISTOR: Electrical device made of semi-conducting material and using at least three electrical connections. Often used as a switching device.

TRANSISTOR IGNITION: Form of ignition system utilizing transistors and a special coil. Conventional distributor and point setup is used. With transistor unit, voltage remains constant, thus permitting high engine rpm without resultant engine "miss." Point life is greatly extended as transistor system passes a very small amount of current through points.

TRANSISTORIZED: Electronic device employing transistors. Can also refer to electronic, as opposed to mechanical, control or operation of some function, such as making and breaking ignition primary circuit.

TRANSMISSION: Device that uses gearing or torque conversion to effect a change in ratio between engine rpm and driving wheel rpm. When engine rpm goes up in relation to wheel rpm, more torque but less speed is produced. Reduction in engine rpm in relation to wheel rpm produces a higher road speed but delivers less torque.

TRANSMISSION ADAPTER: A unit that allows a different make or year transmission to be bolted up to original engine.

TRANSMISSION (Automatic): Transmission that automatically effects gear changes to meet varying road and load conditions. Gear changing is done through series of oil operated clutches and bands.

TRANSMISSION BRAKE: A brake of either drum or disc design, working at transmission. Stops rotation of propeller shaft.

TRANSMISSION (Standard or Conventional): Transmission that must be shifted manually to effect a change in gearing.

TRANSVERSE LEAF SPRING: Leaf spring mounted at right angles to length of car.

TRANSVERSE MOUNTED: Mounted crosswise or at right angles to vehicle centerline.

TRAPS: Area over which car is raced for timing purposes.

TREAD: Distance between two front or two rear wheels.

TREAD (Tire): Portion of tire which contacts roadway.

TREAD PLY (Radial tire): Reinforcing plies lying beneath tread area. These are in addition to body plies that also pass under tread.

TREAD WIDTH (Tire): Distance between outside edges of tread as measured across tread surface.

TRICKLE CHARGING: Maintaining a charge in a stored battery by passing a constant, but very low current, through the battery.

TRIP ODOMETER: Auxiliary odometer that may be reset to zero at option of driver. Used for keeping track of mileage on trips up to one thousand miles.

TROUBLE CODES: Numerical value that represents an abnormal operating condition as detected by a self-diagnostic system. These codes are usually extracted from the computer's memory during service.

TROUBLESHOOTING: Diagnosing engine, transmission, etc., problems by various tests and observations.

TRS: Transmission Regulated Spark.

TRUNNION: One of two pivots, bearings, etc., placed opposite to each other so as to permit a swiveling or tilting action of some part. Example: Universal joint trunnion (yoke bearings) that allow cross to swivel.

TUBE CUTTER: Tool used to cut tubing by passing a sharp wheel around tube.

TUBELESS (Tire): Tire constructed for use without inner tube, valve stem snaps into and seals in wheel rim.

TUNE-UP: Process of checking, repairing, and adjusting carburetor, spark plugs, points, belts, timing, etc., in order to obtain maximum performance from engine.

TUNE-UP SPECIALIST: Person highly trained and skilled in area of engine tune-up. Checks operation of and corrects problems in ignition, fuel, charging, cooling, cranking, etc., systems.

TURBINE: Wheel upon which series of angled vanes are affixed so moving column of air or liquid will impart a turning motion to wheel.

TURBINE ENGINE: Engine that utilizes burning gases to spin a turbine, or series of turbines, as a means of propelling the car.

TURBOCHARGER: Exhaust powered supercharger.

TURBULENCE: Violent, broken movement or agitation of a fluid or gas.

TURNING RADIUS: Diameter of circle transcribed by outer front wheel when making a full turn.

TV ROD: Throttle valve rod that extends from foot throttle linkage to throttle valve in automatic transmission.

TVS: Thermostatic Vacuum Switch.

TWIST DRILL: Metal cutting drill with spiral flutes (grooves) to permit exit of chips while cutting.

TWO-STOKE CYCLE ENGINE: Engine requiring one complete revolution of crankshaft to fire each piston once.

U

UAW: United Auto Workers.

U-BOLT (Spring): A horseshoe shaped bolt, with threads on each end, that passes around axle housing to secure leaf spring.

UMBRELLA SEAL (Valve): A cover placed over valve stem end and extending out over valve spring. Directs dripping oil away from stem and guide area to minimize oil leakage past valve guides.

UNC (Thread): Unified National Coarse thread sizes.

UNDERCOATING: Soft deadening material sprayed on underside of car, under hood, trunk lid, etc.

UNDER-SQUARE ENGINE: Engine in which bore diameter is smaller than length of stroke.

UNDERSTEER: Tendency for car, when negotiating a corner, to turn less sharply than driver intends.

UNEF (Thread): Unified National Extra Fine thread sizes.

UNF (Thread): Unified National Fine thread size.

UNIT BODY: Car body in which body itself acts as frame.

UNIT LOADING: Applying a loading force to very specific area or part, such as is done by adding a crimp, wire, etc., to a gasket to increase pressure around an opening, etc.

UNIVERSAL JOINT: Flexible joint that will permit changes in driving angle between driving and driven shaft.

UNLEADED GASOLINE: Gasoline not containing tetraethyl lead. Must be used with vehicles equipped with a catalytic converter.

UNSPRUNG WEIGHT: All parts of car not supported by suspension system; wheels, tires, etc.

UPDRAFT CARBURETOR: Carburetor in which the air passes upward through the carburetor into the intake manifold.

UPSET: Widening of diameter through pounding.

UPSHIFT: Shifting to a higher gear.

UTQGS: Uniform Tire Quality Grading System.

V

VACUUM: Enclosed area in which air pressure is below that of surrounding atmospheric pressure.

VACUUM ADVANCE (Distributor): Unit designed to advance and retard ignition timing through action of engine vacuum working on a diaphragm.

VACUUM AMPLIFIER: A device used to increase force or action produced by a vacuum.

VACUUM BOOSTER: Small diaphragm vacuum pump, generally in combination with fuel pump, used to bolster engine vacuum during acceleration so vacuum operated devices continue to operate.

VACUUM GAUGE: Gauge used to determine amount of vacuum in a chamber.

VACUUM MODULATOR: Device which uses engine vacuum to control throttle valve in automatic transmission.

VACUUM MOTOR: A device, utilizing a vacuum operated diaphragm, which causes movement of some other unit.

VACUUM PUMP: Diaphragm type of pump used to produce vacuum.

VACUUM RUNOUT POINT: Point reached when vacuum brake power piston has built up all the braking force it is capable of with vacuum available.

VACUUM SWITCH (Electric): An electrical switch that is operated by vacuum.

VACUUM TANK: Tank in which vacuum exists. Generally used to provide vacuum to power brake installation in event engine vacuum cannot be obtained. Tank will supply several brake applications before vacuum is exhausted.

VALVE: Device used to either open or close an opening. There are many different types.

VALVE BODY (Automatic transmission): Unit containing various shifter valves, springs, passageways, etc. Used to control transmission shift operation.

VALVE CLEARANCE (Engine): Space between end of valve stem and actuating mechanism (rocker arm, lifter, etc.)

VALVE DURATION: Length of time, measured in degrees of engine crankshaft rotation, that valve remains open.

VALVE FACE: Outer lower edge of valve head. The face contacts the valve seat when the valve is closed.

VALVE FACE ANGLE: See Face Angle.

VALVE FLOAT: Condition where valves in engine are forced back open before they have had a chance to seat. Brought about (usually) by extremely high rpm.

VALVE GRINDING: Renewing valve face area by grinding on special grinding machine.

VALVE GUIDE: Hole through which stem of poppet valve passes. It is designed to keep valve in proper alignment. Some guides are pressed into place and others are merely drilled in block or in head metal.

VALVE HEAD (Engine): Portion of valve above stem.

VALVE-IN-HEAD ENGINE: Engine in which both intake and exhaust valve are mounted in the cylinder head and are driven by push rods or by an overhead camshaft.

VALVE KEEPER or VALVE KEY or VALVE RETAINER: Small unit that snaps into a groove in end of valve stem. Designed to secure valve spring, valve spring retaining washer, and valve stem together. Some are of split design and some are horseshoe shaped.

VALVE LASH: Valve tappet clearance or total clearance in the valve operating train with cam follower on camshaft base circle.

VALVE LIFT: Distance a valve moves from full closed to full open position.

VALVE LIFTER or CAM FOLLOWER: Unit that contacts end of valve stem and camshaft. Follower rides on camshaft. Cam lobes move it upward to open valve.

VALVE MARGIN: Width of edge of valve head between top of valve and edge of face. Too narrow a margin results in preignition and valve damage through overheating.

VALVE OIL SEAL: Neoprene rubber ring placed in groove in valve stem to prevent excess oil entering area between stem and guide. There are other types of these seals.

VALVE OVERLAP: Certain period in which both intake and exhaust valve are partially open. (Intake is starting to open while exhaust is not yet closed.)

VALVE PORT: Opening, through head or block, from intake or exhaust manifold to valve seat.

VALVE ROTATOR: Unit that is placed on end of valve stem so that when valve is opened and closed, the valve will rotate a small amount with each opening and closing. This gives longer valve life.

VALVE SEAT: Area onto which face of poppet seats when closed. Two common angles for this seat are forty-five and thirty degrees.

VALVE SEAT GRINDING: Renewing valve seat area by grinding with a stone mounted upon a special mandrel.

VALVE SEAT INSERT: Hardened steel valve seat may be removed and replaced.

VALVE SEAT RUNOUT: A measurement of valve seat out-of-roundness (concentricity). Also provides an indication of seat squareness with valve guide centerline.

VALVE SPRING: Coil spring used to keep valves closed.

VALVE SPRING COMPRESSOR: Tool used to collapse valve spring so that retainer may be removed.

VALVE STEM (Engine): Portion of valve below head. The stem rides in the guide.

VALVE STEM CLEARANCE: Clearance between stem and guide.

VALVE TAPPET: Adjusting screw to obtain specified clearance at end of valve stem (tappet clearance). Screw may be in top of lifter, in rocker arm, or in the case of ball joint rocker arm, nut on mounting stud acts in place of a tappet screw.

VALVE TIMING: Adjusting position of camshaft to crankshaft so that valves will open and close at the proper time.

VALVE TRAIN: Various parts making up valve and its operating mechanism.

VALVE UMBRELLA: Washer-like unit placed over end of the valve stem to prevent entry of excess oil between stem and guide. Used in valve-in-head installations.

VANE: Thin plate affixed to rotatable unit to either throw off air or liquid, or to receive thrust imparted by moving air or liquid striking the vane. In the first case it would be acting as a pump and in the second case as a turbine.

VANE PUMP: Pump using two or more spring loaded vanes (flat, rectangular strips) operating in slots in a rotor. As rotor spins, vane ends rotate and rub against pump walls. Rotor is offset in relation to pump walls.

VAPOR: Gaseous state of a substance usually a liquid or solid. Example: Steam.

VAPOR CHARGING: Charging air conditioning system with R-12 vapor.

VAPORIZATION: Breaking gasoline into fine particles and mixing it with air.

VAPOR-LIQUID SEPARATOR: A device used to separate liquid from a vapor—such as can be used in an engine PCV system to prevent engine oil being drawn out of engine along with crankcase vapors.

VAPOR LOCK: Boiling or vaporizing of the fuel in the lines from excess heat. Boiling will interfere with movement of the fuel and will in some cases, completely stop the flow.

VAPOR SEPARATOR: A device used on cars equipped with air conditioning to prevent vapor lock by feeding vapors back to the gas tank via a separate line.

VARIABLE PITCH STATOR: Stator that has vanes that may be adjusted to various angles depending on load conditions. Vane adjustment will increase or decrease efficiency of stator.

VARIABLE VENTURI: A carburetor venturi whose opening size can be varied to meet changing engine speed and load.

VARNISH: Deposit on interior of engine caused by engine oil breaking down under prolonged heat and use. Certain portions of oil deposit themselves in hard coatings of varnish.

V-BELT: V shaped belt commonly used to spin alternator, water pump, power steering pump, and air conditioning compressor.

V-BLOCK: A block of steel with a deep “V” groove cut in one or more spots. Can be used in pairs to support a shaft while it is turned to check for runout, support round work for drilling, etc.

VELOCITY: Time rate of motion. Speed with which an object moves as measured in feet per second, miles per hour, etc.

VENTURI: That part of a tube, channel, or pipe so tapered as to form a smaller or constricted area. Liquid, or a gas, moving through this area will speed up and as it passes narrowest point, a partial vacuum will be formed. Taper facing flow of air is much steeper than taper facing away from flow of air. Venturi principle is used in carburetor.

VIBRATION DAMPER: Round weighted device attached to front of crankshaft to minimize torsional vibration.

VISCOSIMETER: Device used to determine viscosity of a given sample of oil. Oil is heated to specific temperature and then allowed to flow through set orifice. Length of time required for certain amount of flow determines oil’s viscosity.

VISCOSITY: Measure of oil’s ability to pour.

VISCOSITY INDEX: Measure of oil’s ability to resist changes in viscosity when heated.

VISCOSITY RATING: A rating of how “thick” or “thin” a sample of oil may be. This refers to how fast a given amount will flow through a specific size hole at a given temperature.

VISCOUS COUPLING: A nondirect coupling (driving unit) between two drive components that utilizes a fluid (such as silicone) to produce transfer of power. Allows for some slippage.

VOLATILE: A substance that evaporates (turns to vapor) easily. Example: Gasoline.

VOLATILITY: Property of gasoline, alcohol, etc., to evaporate quickly and at relatively low temperatures.

VOLT: Unit of electrical pressure or force that will move a current of one ampere through a resistance of one ohm.

VOLTAGE: Difference in electrical potential between one end of a circuit and the other. Also called EMF (electromotive force). Voltage causes current to flow.

VOLTAGE DROP: Lowering of voltage due to excess length of wire, undersize wire, etc.

VOLTAGE REGULATOR: See Regulator—Voltage.

VOLTMETER: Instrument used to measure voltage in given circuit. (In volts.)

VOLUME: Measurement, in cubic inches, cubic feet, etc., of amount of space within a certain object or area.

VOLUMETRIC EFFICIENCY: Comparison between actual volume of fuel mixture drawn in on intake stroke and what would be drawn in if cylinder were to be completely filled.

VORTEX: Mass of whirling liquid or gas.

VORTEX FLOW (Torque converter): Whirling motion of oil as it moves around from pump, through turbine, stator and back into pump and so on.

V-TYPE ENGINE: An engine with cylinders arranged in two separate banks (rows) and set at an angle (V-shape) to each other.

VULCANIZATION: Process of heating compounded rubber to alter its characteristics—making it tough, resilient, etc.

W

WANDERING (Steering): Condition in which front wheels tend to steer one way and then another.

WANKEL ENGINE: Rotary combustion engine having one or more three-sided rotors mounted on drive shaft operating in specially shaped chambers. Rotor turns constantly in one direction yet produces an intake, compression, firing, and exhaust stroke.

WARPAGE: Bending or twisting of an object caused by heat, improper fastener torque, etc.

WATER DETECTOR: Sensor in diesel fuel system which warns driver of water contamination of fuel.

WATER JACKET: Area around cylinders and valves that is left hollow so that water may be admitted for cooling.

WATER PUMP: The pump, usually a centrifugal type, used to circulate coolant throughout cooling system.

WATER SENSOR (Diesel): A device in a diesel fuel system to detect presence of water in fuel.

WATT (Electrical): A unit of electrical power amounting to one joule per second.

WAVEFORM or PATTERN (Oscilloscope): Visible pattern produced on an oscilloscope screen.

WEDGE: Engine using wedge-shaped combustion chamber.

WEDGE COMBUSTION CHAMBER: Combustion chamber utilizing wedge shape. It is quite efficient and lends itself to mass production and as a result is widely used.

WEIGHT (Curb): Weight of vehicle (no passengers) with all systems (fuel, cooling, lubrication) filled.

WEIGHT (Shipping): Basic vehicle weight including all standard items but without fuel or coolant.

WEIGHT (Sprung): See Sprung Weight.

WEIGHT DISTRIBUTION: Percentage of total vehicle weight as carried by each axle (front and rear).

WELCH PLUG: Another term for engine sand casting core hole plug. Also called "freeze plug."

WELD: To join two pieces of metal together by raising area to be joined to point hot enough for two sections to melt and flow together. Additional metal is usually added by melting small drops from end of metal rod while welding is in progress.

WELD BEAD: Layer of metal deposited during a welding operation.

WET FRICTION: Resistance to movement between two lubricated surfaces.

WET SLEEVE: Cylinder sleeve application in which water in cooling system contacts a major portion of sleeve itself.

"WET" STEAM: Steam containing heavier water droplets that have not been fully vaporized.

WHEEL ALIGNER: Device used to check camber, caster, toe-in, etc.

WHEEL ALIGNMENT: Refers to checking or adjusting various angles involved in proper placement or alignment of both front and rear wheels.

WHEEL BALANCER: Machine used to check wheel and tire assembly for static and dynamic balance.

WHEELBASE: Distance between center of front wheels and center of rear wheels.

WHEEL BEARING: Ball or roller bearings on which wheel hub rotates.

WHEEL BRAKE: A brake operating at wheel, either drum or disc design.

WHEEL CYLINDER: Part of hydraulic brake system that receives pressure from master cylinder and in turn applies brake shoes to drums.

WHEEL DOLLY: A wheeled device used to elevate and install heavy truck wheel and tire assemblies.

WHEEL HOP: Hopping action of rear wheels during heavy acceleration.

WHEEL HUB: That unit upon which wheel is fastened.

WHEELIE BARS: Short arms attached to rear of a drag racer to prevent front end from rising too far off ground during heavy acceleration. Arms are usually of spring material and have small wheels attached to ends that contact ground.

WHEEL LUG or LUG BOLT: Bolts used to fasten wheel to hub.

WIDE TREADS, WIDE OVAL, etc: Wide tires. Tire height (bead to tread surface) is about 70 percent of tire width across outside of carcass.

WINCH: An electrically or mechchanically driven drum that will wind in a length of cable. Used to remove vehicles from mud, ascend very steep slopes, pull logs, etc.

WINDSCREEN: British term for windshield.

WIRE GAUGE: A steel plate with a number of various size openings. Used to determine wire diameter and thickness of sheet metal.

WIRE LOOM: A woven covering through which one or more wires can be passed. Secures and protects wires.

WIRE WHEEL: A vehicle wheel using a series of wire (round steel rods) spokes. May also refer to a cleaning wheel made up of wire bristles.

WIRING DIAGRAM: Drawing showing various electrical units and wiring arrangement necessary for proper operation.

WIRING HARNESS: A series of wires bound together to form a handy, compact, and protected unit. Often sheathed in a protective covering.

WISHBONE: Radius rod setup used in many older Ford cars to keep axle square with frame.

WITNESS MARKS: Punch marks used to position or locate some part properly.

WOBBLE PLATE: A round, flat plate with a shaft passing through its center. Plate is affixed to shaft at an angle to shaft centerline. When shaft turns, plate rotates and also wobbles from side to side. Used on axial air conditioning compressor to operate pistons.

WOODRUFF KEY: A half round key inserted in a circular slot in a shaft. Protrudes above shaft into a part keyway to prevent turning.

WORK: A force applied to a body causing body to move.

WORK HARDENING: Hardening of a material by bending, pounding, vibration, etc.

WORM AND ROLLER: Steering gear utilizing a worm gear on steering shaft. A roller on one end of cross shaft engages worm.

WORM AND SECTOR: Type of steering gear utilizing worm gear engaging sector (a portion of a gear) on cross shaft.

WORM AND TAPER PIN: Steering gear utilizing worm gear on steering shaft. End of cross shaft engages worm via taper pin.

WORM GEAR: A long, cylindrical gear containing a continuous spiral tooth (thread-like). Gear centerline is at right angles to centerline of worm wheel.

WORM SHAFT (Steering): Steering gear shaft upon which a worm gear is formed. Turns pitman shaft.

WRENCH — ADJUSTABLE: A wrench in which two parallel jaws may be adjusted open or closed by action of a small worm gear. Often called "Crescent wrench."

WRENCH — ALLEN: A hexagonal shaped wrench used to insert into and turn, Allen screws.

WRENCH — BOX END: Double-end wrench with six or twelve point opening at each end.

WRENCH — COMBINATION: Double-end wrench with a box end on one end and an open end on other.

WRENCH — FLARE NUT: Wrench, similar to a box end but with a section of box cut away. Used to turn tubing nuts.

WRENCH — FLEX HEAD: Wrench with a swivel socket on each end.

WRENCH — FLUTED: Wrench, similar to an Allen wrench but with a series of flutes (grooves) that fit into a corresponding hole in fastener.

WRENCH — OPEN END: Double-end wrench with fixed, parallel jaws.

WRENCH — PIPE (Inside & outside): Wrench with toothed jaws designed to bite into pipe to prevent slipping.

WRENCH — RATCHET BOX END: Wrench with a box end arrangement that is free to ratchet. Allows wrench to be moved back and forth without removing it from fastener.

WRENCH – STUD: Wrench designed to grasp stud shank for insertion or removal.

WRIST PIN: See Piston Pin.

Y

YIELD STRENGTH (Elastic limit): Maximum force (in pounds per square inch) that can be sustained by given member and have that member return to its original position, length, shape, etc., when force or pressure is removed.

YOKE: Slotted or split end of an object that straddles and is fastened to another, such as a universal joint yoke straddles cross or spider.

Z

ZENER DIODE: A silicone diode that serves as a rectifier (allows electrical current flow in ONE direction only) until voltage being applied to diode attains a certain level (called Zener voltage) at which point diode becomes conductive.

ZERO DEFECTS: In manufacturing, taking extreme care to make something so well that there will be no failures caused by faulty workmanship or parts.

ZINC: A metal used in plating steel panels, parts, etc., to help prevent rusting and corrosion.

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